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**MODERN HEAT-TREATMENT OF STEEL**

*by*

A. CRAIG McDONALD, B.Sc., A.R.I.C., M.I.A.E.

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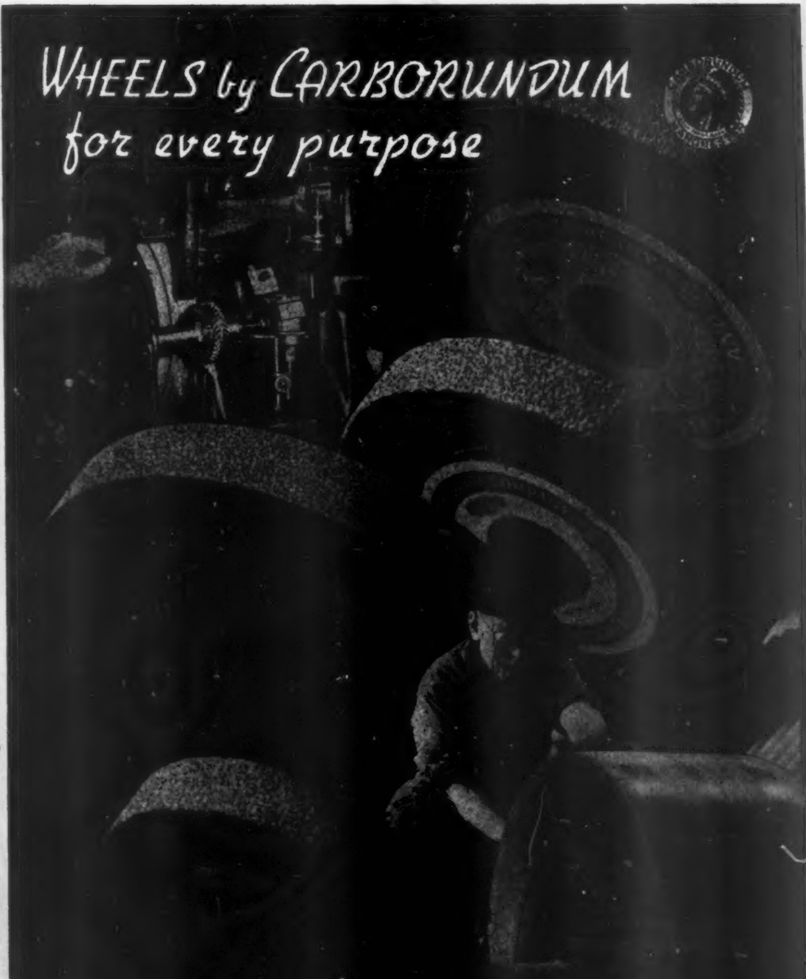
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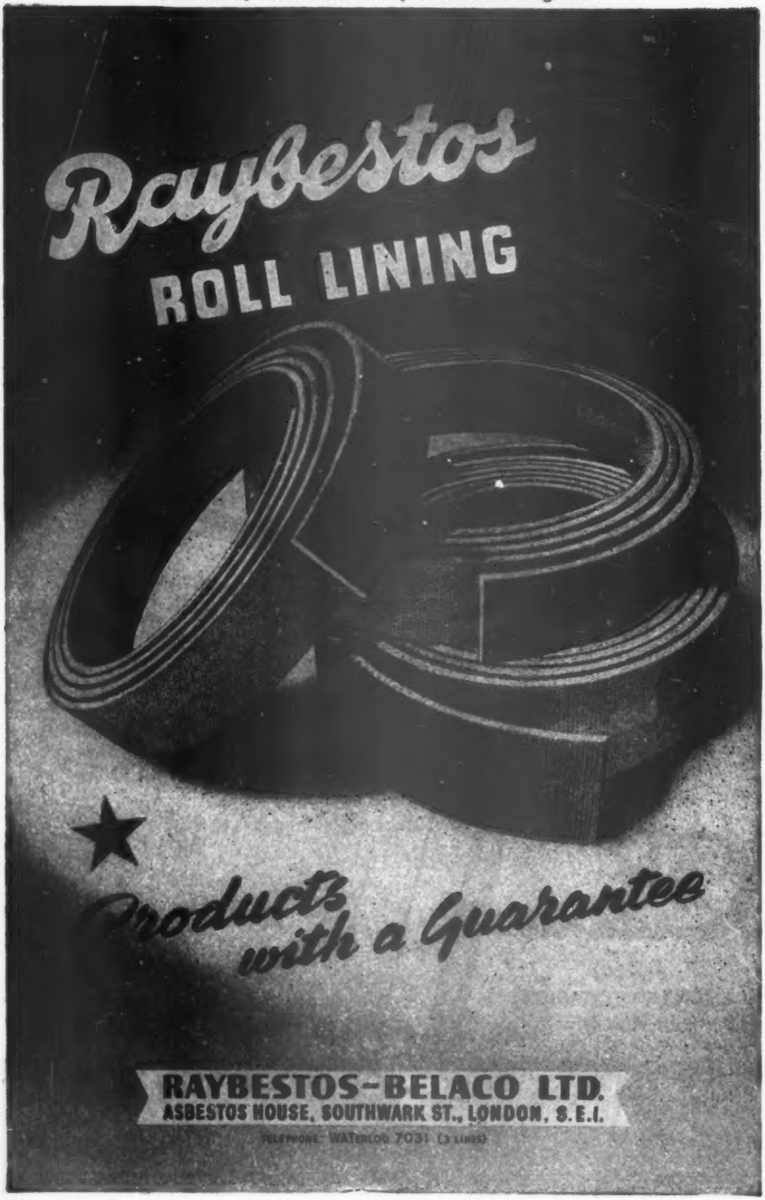
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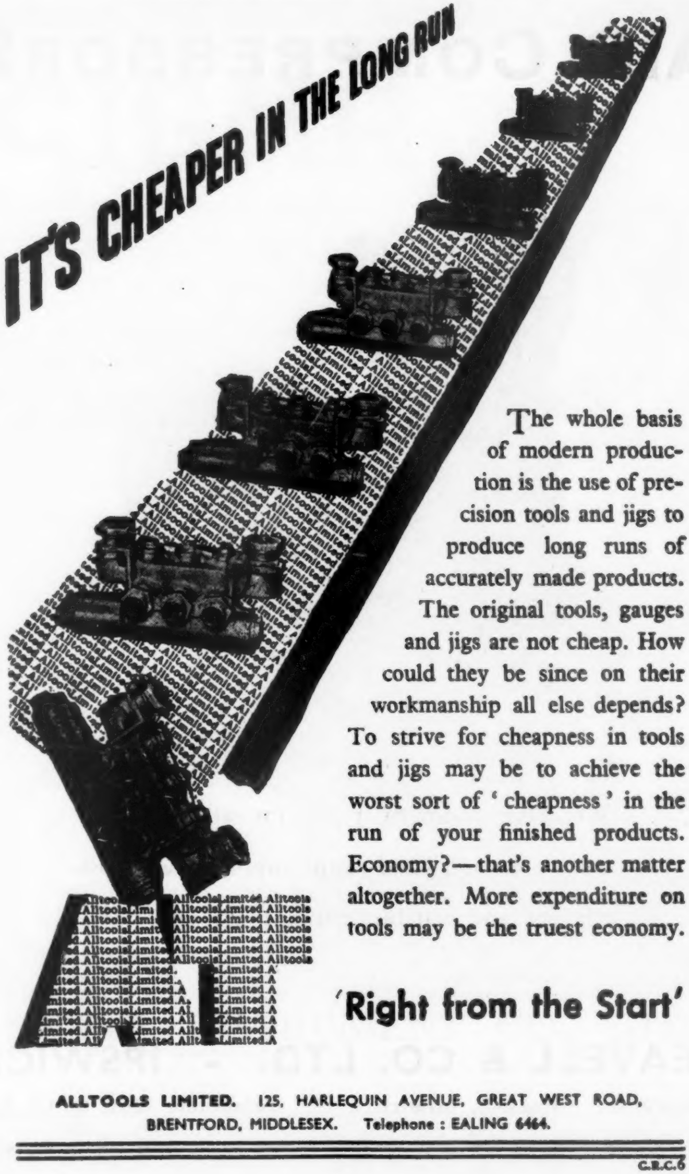
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# MODERN HEAT TREATMENT OF STEEL

By A. Craig Macdonald, B.Sc., A.R.I.C., M.I.A.E.

*Paper presented to the Scottish Section of The Institution of Production Engineers on 15th March, 1945, and read before the London Section on 13th December, 1945.*

The metallic substances which we use for structural and automotive purposes are not products of nature, but are man-made and artificial in the sense that natural substances have been purified and deoxidised and alloyed in order to give us the range of ferrous and non-ferrous materials available to the engineer to-day. Their properties are, nevertheless, controlled fundamentally by laws that man did not make and many of these laws are still understood but partially by the pure scientist and not at all by the rest of us.

An engineer knows that steel has certain modulus of elasticity and that when a beam is loaded with a certain weight it will deflect a calculable amount. He does not know why steel should have a modulus around 30 million lbs. per sq. in. and aluminium a modulus about a third of that, but he accepts it as a fact. It is greatly to be regretted that he is not equally ready to accept the facts of metallurgy because in this science as in his own, there are many things imperfectly understood by all concerned that we must simply acknowledge as humbly as may be and get on with the job.

The conclusion may emerge from some of my later remarks that we can exercise some control over the properties of our materials, but it should be emphasised at this stage that the control can be exercised within narrow limits only and some of the results we are asked to produce must in the meantime be regarded simply as an inspiration to the rising generation in the search for nobler substances.

We cannot discuss the subject of heat-treatment without quickly being involved in questions of temperature and while we are still in the philosophical portion of this paper it should be emphasised that we have our being in a portion of temperature scale which has the disadvantage of being neither at the one end nor at the other. We exist on the earth's surface at temperatures varying between minus 50 degrees and plus 50 degrees on what we choose to call the Centigrade scale with a marked tendency towards the lower figure in many familiar localities. But the lower figure is still 223 degrees above absolute zero and between absolute zero and the temperature of the body of the sun the properties of materials vary to a wide extent. Mercury nails can be driven into wood with ease at temperatures attainable by modern refrigeration methods and iron becomes

gaseous in the electric arc. It is rarely convenient to make use of the properties materials possess at temperatures outside the limits of the atmospheric temperature and a few hundred degrees above it. However, in considering heat-treatment problems, this inconvenient fact that atmospheric temperature is not an absolute temperature must receive attention. When we heat a piece of steel we add to the thermal units already there. We alter its temperature in the direction of incandescence, but having acquired some knowledge of the disastrous results of approaching incandescence too closely we catch it before it goes too far and cool again. We are confident that on its way down to absolute zero it will once again be arrested by the temperature of its surroundings which may vary with the season and with the local conditions.

We have discovered that a good deal depends on the rate of the cooling and we know that the rate is easy to control when it is slow, but comparatively difficult to keep within a certain speed limit when the rate required is fast, as it very often is. We know, too, that the correct temperatures and cooling rates vary as a result of variations in composition which must be regarded as inevitable. We cannot even check the composition with absolute precision, nor can we

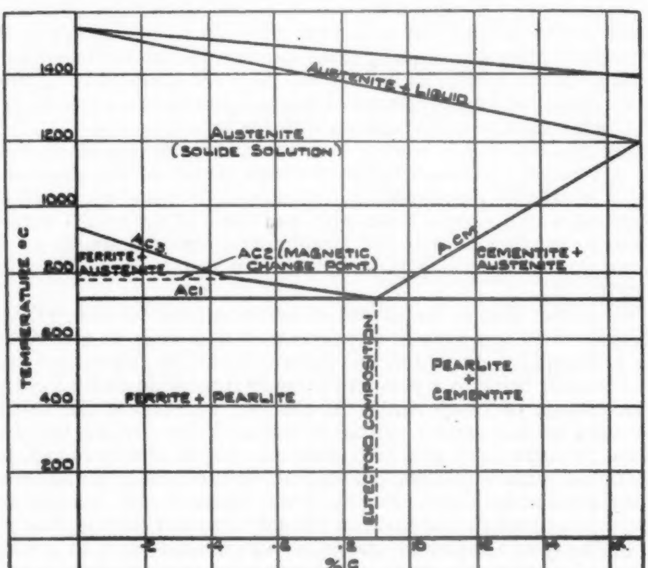


Fig. 1

check the temperatures exactly once we have decided what we think they should be.

So what do we do commercially? We take a piece of material whose approximate composition is known and heat it to a temperature measured with an error between 1 and 5 per cent., depending on the quality of the equipment and cool it as near the proper rate as we can with the miserably few cooling media readily available to us to-day. We finally test the product with the comforting thought that the specification—if a standard one—was prepared fairly generously in view of the difficulties involved and very generously if we had the authority and the sense to prepare it ourselves.

I would like now to remove any misapprehension which may have arisen from the title of this paper. Many of the basic principles governing heat-treatment processes have long been established and this paper deals with modern heat-treatment only in the sense that some of the most recent developments will receive a good deal of attention, while older methods—still widely practised—may not even be mentioned as most of them have already been described adequately in the proceedings of this and other technical societies.

In the paper I shall avoid, as far as possible, purely metallurgical considerations and may even sacrifice a little metallurgical accuracy where the sacrifice simplifies our consideration of a problem without affecting it from the points of view of the engineer and the heat-treatment department foreman. On the other hand no apology is made for the references to austenite and martensite, etc., because no real effort can be made to understand heat-treatment processes unless some attention is paid to these constituents of steel and in any event they are already becoming familiar to engineers because they are nowadays used quite freely in the descriptions of certain types of steel.

Steel is the material with which heat-treatment processes are still most widely associated and it may make my comment on it more complete and more readily understood if I give now a very brief summary of the effect of composition.

Steel, in its simplest form is essentially iron containing a small percentage of carbon and some impurities. The carbon is not free carbon like the graphite in cast iron, but is present as iron carbide in various forms. In low carbon steel in the soft condition, the carbide is present as pearlite in a matrix of iron. This matrix is commonly referred to in the metallurgical world as ferrite. In high carbon steels another form of carbide appears which is known as cementite.

The various carbon steels may, therefore, be distinguished as follows:—

Carbon under 0·89 per cent.—pearlite and ferrite.
Carbon precisely 0·89 per cent.—pearlite only.
Carbon over 0·89 per cent.—pearlite and cementite.

In heating such steels there are three critical points at which certain changes take place. (Fig. 1.) At the lower critical point, or $Ac_1$ point, the pearlite changes to austenite,but any ferrite remains unchanged. As the temperature is increased, the austenite dissolves the ferrite gradually and at an intermediate critical point known as the $Ac_2$ point it has dissolved sufficient of the ferrite to alter the magnetic properties of the steel. At the upper critical point known as the $Ac_3$ point, all the ferrite is dissolved and we have therefore a complete solid solution that is entirely austenite.

| Spec. | C. % | S. % | P. % | Mn. % | N. % | Cr. % | Mo. % | Condition. | U.S. tons/ sq. in. | Elon. % | Izod ft./ lbs. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| V2 | 0·20 max. | 0·06 max. | 0·06 max. | 0·80 max. | — | — | — | Hot rolled or normalised<br>Annealed<br>Cold rolled | 26 min.<br>20 ,,<br>30 ,, | 28 min.<br>28 ,,<br>20 ,, | —<br>—<br>— |
| V3 | 0·15/ 0·25 | 0·06 max. | 0·06 max. | 0·40/ 0·80 | — | — | — | As rolled or normalised<br>Cold drawn | 28/33<br>35/45 | 25 min.<br>15 ,, | —<br>— |
| V4 | 0·28/ 0·38 | 0·06 max. | 0·06 max. | 0·60/ 1·00 | — | — | — | As rolled or normalised | 32 min. | 25 min. | — |
| V4A | 0·35/ 0·45 | 0·06 max. | 0·06 max. | 0·60/ 1·00 | — | — | — | As rolled or normalised | 35 min. | 20 min. | — |
| V4B | 0·45/ 0·55 | 0·06 max. | 0·06 max. | 0·70/ 1·00 | — | — | — | As rolled or normalised | 40 min. | 15 min. | — |
| V5 | 0·50/ 0·60 | 0·60 max. | 0·06 max. | 0·50/ 0·80 | — | — | — | Normalised<br>Cold drawn | 45 min.<br>50/65 ,, | 18 min.<br>12·5 ,, | —<br>— |
| V7 | 0·30/ 0·38 | 0·06 max. | 0·06 max. | 1·30/ 1·70 | — | — | — | Heat-treated | 50 min. | 20 min. | 25 |
| V9A | 0·30/ 0·38 | 0·05 max. | 0·05 max. | 1·30/ 1·80 | — | — | 0·20/ 0·35 | Heat-treated | 60 min. | 17 min. | 35 |
| V9D | 0·35/ 0·45 | 0·05 max. | 0·05 max. | 0·50/ 0·80 | — | 0·90/ 1·20 | 0·20/ 0·35 | Heat-treated | 65 min. | 16 min. | 35 |
| V10 | 0·35/ 0·43 | 0·05 max. | 0·05 max. | 0·50/ 0·70 | 1·30/ 1·80 | 0·90/ 1·40 | 0·20/ 0·35 | Heat-treated | 70 min. | 15 min. | 30 |
| V11 | 0·27/ 0·35 | 0·05 max. | 0·05 max. | 0·50/ 0·70 | 2·30/ 2·80 | 0·50/ 0·80 | 0·40/ 0·70 | Heat-treated | 80 min. | 14 min. | 25 |
| V13 | 0·26/ 0·34 | 0·05 max. | 0·05 max. | 0·40/ 0·60 | 3·90/ 4·30 | 1·10/ 1·40 | — | Heat-treated | 100 min. | 10 min. | 10 |

Fig. 2

The precise temperatures at which these change points exist depend on the composition of the steel. As the carbon content is increased the upper critical point comes down until it coincides with the intermediate or $Ac_2$ point, when the carbon content is between 0·4 and 0·5 per cent. As the carbon is further increased to 0·89 per cent., at which figure no free ferrite exists, the $Ac_1$ point also merges with the other two and we have but one single change point with this composition of steel.

It is the upper critical point with which we are mainly concerned in heat-treatment operations such as normalising or hardening. Suitable temperatures for these operations are slightly in excess of the upper critical point and typical figures are 900°C. for steel containing carbon up to 0·18 per cent., 850°C. for a carbon content between 0·35 and 0·40 per cent. and 780°C. where the carbon is around 0·90 per cent.

There are also critical points when steels are cooled from high temperatures, but these need be mentioned only in certain instances later in the paper.

Please note that the changes at any of the critical points are not instantaneous. They require some time, whether it be seconds or hours, depending on the type of steel.

We will pursue the subject of hardening a little further. When a piece of plain carbon steel is heated beyond the upper critical point a little and cooled very rapidly by quenching in water, we in effect make an effort to retain it in the austenitic condition which obtains at the hardening temperature. Change of structure requires time and we are quenching violently to reduce the available time. This effort is, however, normally unsuccessful because the cooling rate is not fast enough and the austenite decomposes into martensite. Whereas austenite is soft and ductile, the decomposition product, martensite, is very hard and brittle. It is to the formation of this martensite by decomposition of austenite that we owe our ability to harden steel.

In a low carbon steel of, say, 0·20 per cent., the percentage of carbide is small and the amount of martensite formed is therefore also small and the degree of hardening is not marked. In high carbon steels containing around 1 per cent. carbon, full hardening is obtained. With carbon contents of over 1 per cent. and a severe quench in brine, some austenite can be retained along with the martensite—but more of that anon.

It is seldom desirable to use steel in the fully hardened condition and it is therefore usually tempered. In tempering, the steel is reheated to a temperature entirely dependent on the degree of softening or toughening required, but the temperature is always below the $Ac_1$ change point of the material. The effect of the tempering heat is to decompose the martensite and the products are

troostite and/or sorbite and/or pearlite formed in that order as the tempering temperature is raised. We may, therefore, have any degree of hardness or strength we wish between the figures obtainable from the fully hardened material and those characteristic of it in the fully tempered or fully softened condition.

| Steel Spec. No. | Minimum Mechanical Properties. | | | Limiting Section. |
|---|---|---|---|---|
| | Ult. Stress. | Elongation. | Izod. | |
| V4A ... ... | 40 | 22 | 15 | 2½ in. |
| V7 ... ... | 50 | 20 | 25 | 1⅛ in. |
| | 45 | 20 | 20 | 4 in. |
| V9A ... ... | 60 | 17 | 28 | 1⅛ in. |
| | 55 | 18 | 32 | 2½ in. |
| | 50 | 20 | 32 | 4 in. |
| | 45 | 20 | 32 | 6 in. |
| V11 ... ... | 100 | 10 | 8 | 4 in. |
| | 80 | 12 | 20 | 6 in. |
| V13 ... ... | 100 | 10 | 10 | 6 in. |

Fig. 3.

It would perhaps be desirable at this stage to give the British Standard definitions of the ordinary heat-treatment terms.

**Normalising.**

Normalising means heating a steel (however previously treated) to a temperature exceeding its upper critical range and allowing it to cool freely in the air. It is desirable that the temperature of the steel shall be maintained for about 15 minutes and shall not exceed the upper limit of the critical range by more than 50 degrees Centigrade.

**Annealing.**

Annealing means re-heating followed by slow cooling. Its purposes may be :—

(i) To remove internal stresses or to induce softness in which cases the maximum temperature may be arbitrarily chosen.

(ii) To refine the crystalline structure in addition to the above (i), in which case the temperature used must exceed the upper critical range as in normalising.

**Hardening.**

Hardening means heating a steel to its normalising temperature and cooling more or less rapidly in a suitable medium, *e.g.*, water, oil or air.

**Tempering.**

Tempering means heating a steel (however previously hardened) to a temperature below its carbon change point with the object of reducing the hardness or increasing the toughness to a greater or less degree.

**Softening.**

Softening is to facilitate the machining of a steel and is carried out by annealing or tempering or both.

**Cementing** (or Carburising as it is more commonly called).

Cementing means heating a steel above its normalising temperature in a medium which will increase the carbon content. The core of a casehardened bar is the interior portion of the bar which is substantially unaffected in composition by the cementing process.

**Refining Cemented (Carburised) Parts.**

Refining means reheating a steel to its normalising temperature as in normalising. It is usually followed by quenching.

**Spheroidising.**

Spheroidising is any process of heating and cooling steel that produces a rounded or globular form of carbide. This is not a British Standards Definition but an American one.

To review these briefly, I would add that normalising is commonly used to refine the forged structure of wrought steels or to eliminate as far as possible the effects of any previous heat-treatment operation when required, or in general terms to bring any piece of steel into a known, uniform, stable and reasonably refined condition suitable for service or suitable for the application of any further treatment such as hardening or hardening and tempering. With all the low and medium carbon steels the relatively slow cooling from the normalising temperature leaves all the carbon in the pearlitic condition.

Annealing covers quite a variety of heat-treatment processes which differ from normalising in that either the temperature used is lower or the cooling rate is slower or both. In this country it covers spheroidising processes as well as the other forms of annealing, but I consider that the American definition of the latter should be included as it is of considerable interest to engineers in relation to improvement of machinability. Spheroidising methods frequently used are :—

(*a*) Prolonged heating at a temperature just below the lower critical temperature and subsequent slow cooling.

(*b*) Submission of parts to a fluctuating temperature cycle which rises and falls alternately between a point just within the critical range and a point just below the $Ac_1$ point.

(*c*) Tool steel may be spheroidised by heating to a temperature above the upper critical point, soaking and subsequently cooling very slowly in the furnace.

An excellent booklet on Annealing and Spheroidising Treatments has lately been published by the Crucible Steel Company of America, the author being Payson, their Research Metallurgist.

Hardening and tempering have already received some attention in my own paper and cementing and refining require no comment as they are the essentials of the ordinary casehardening process.

I would like to add only in respect of tempering that the temperature used must be under the lower critical point of the steel being treated. For speed in handling and for the avoidance of temper brittleness parts are normally quenched from the tempering temperature—very often in water. If the tempering temperature is higher than the lower critical point some or all of the pearlite will be changed to austenite and there will, therefore, be partial rehardening on quenching. This may result in extreme brittleness.

So far I have confined myself to plain carbon steels and I would like now to consider, very briefly, the effect of alloys.

Nickel takes precedence over all other metals in the astonishing range of materials with remarkable properties which it has made available for every engineering industry. When used as an addition to steel it dissolves in and strengthens and toughens the ferrite or iron constituent and has a very great influence on heat-treatment.

Nickel lowers the upper critical point so that normalising and hardening temperatures are lower for nickel steels than for the corresponding plain carbon steels. In addition, it reduces considerably the rate of cooling necessary to retain the austenitic condition and therefore it reduces also the other rate of cooling necessary to obtain a fully martensitic hardened structure. This means that :—

(*a*) when 1–3 per cent. of nickel has been added a steel in light sections will harden fully in oil instead of in water ;

(*b*) the effect of mass is reduced because the reason for poor hardening in the core of heavy sections of carbon steels is the relatively slow cooling rate in the core, no matter how severe the quench may be ;

(*c*) as the nickel content is increased the effects noted under "*a*" and "*b*" become more and more marked, in fact a steel containing 13 per cent. nickel will harden satisfactorily when cooled in air ;

(*d*) the effects of still higher nickel content are also notable because the cooling rate to retain the austenitic condition has slowed

down so much that if the high nickel alloys are quenched the austenitic condition obtains at atmospheric temperature. In fact, when the nickel content is 29 per cent., the alloy is wholly austenitic when cooled in air and will not harden at all by normal heat-treatment methods.

Chromium differs in certain respects from nickel in its effect as an addition to steel. It combines with the carbon in steel, dissolving in the iron only partially and raises the upper critical point instead of lowering it, but, like nickel, it reduces the rate of cooling necessary to get adequate hardening. It slows up all the changes which take place in steel structure in heating and cooling and it is therefore not surprising that it reduces the percentage of nickel necessary to produce the martensitic and austenitic types of steel I have just described for nickel additions alone. Steel containing 4 per cent. nickel and 1 per cent. chromium air-hardens with ease and sections up to 4 in. diameter have uniform properties throughout their thickness.

Molybdenum is another important alloying element which forms carbides and in relatively small quantity increases the hardenability of the steel so that by its use in conjunction with nickel and chromium uniformity can be obtained in 6 in. sections.

Manganese resembles nickel in its effect, but smaller percentages of the manganese are required. It is finding wide use to-day in manganese-molybdenum steels giving excellent physical properties in the 55-ton range of ultimate stress.

Vanadium resembles molybdenum and need not concern us greatly here.

Now it should be borne in mind that the hardnesses and tensile strengths obtainable with these alloy steels are still of the same order as those we obtain from carbon steels, but they are obtainable as already emphasised, in much heavier sections and the ductility and Izod value corresponding to any particular tensile strength are much greater. Fig. 2 shows some of the popular steels used in the automotive industry and illustrates the range of properties obtainable in sections $1\frac{1}{8}$ in. diameter.

Fig. 3 is devoted to the effect of mass and shows among other things the best combination of mechanical properties commercially obtainable to-day in 6 in. sections.

There can be little doubt that a good deal of what I have said so far may confuse and even irritate because of the lack of precise knowledge as distinct from intelligent guesswork which bears on the questions of structural changes in different steels, on the temperatures and cooling rates at which they take place, and on the time occupied in completing the changes at any particular temperature. This feeling is to some extent justified and has been shared at some time or another by most people interested in heat-treatment problems.

Fortunately, much work has been done in the past few years, particularly in America, and the United States Steel Corporation has made a contribution to our knowledge of the subject on which they are to be congratulated.

As the transformation of austenite to carbides of various kinds is the basis of changes in mechanical properties by heat-treatment and as it has already been noted that the changes are dependent on time and temperature, we have very valuable information indeed if a plotting can be made over the whole range of both for a particular composition. The first graph of this kind was published in 1930. Unfortunately, each graph requires the treatment and testing of over 100 small specimens, but the United States Steel Corporation has completed the work on 47 different compositions and published the results in what they call their "Atlas of Isothermal Transformation Diagrams." Copies of this valuable publication are not yet readily available in this country, but they will be after the war.

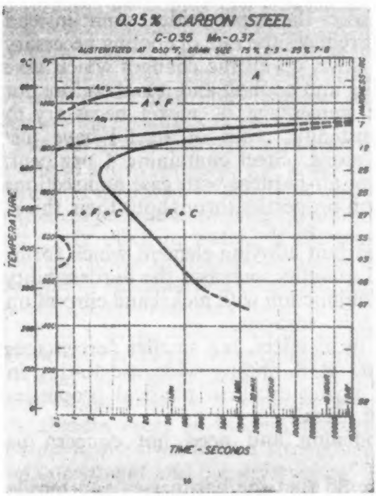

Fig. 4

A typical transformation diagram or S-curve, as it is called, is shown in Fig. 4.

The temperature at which the transformation is taking place is shown on the left in degrees Fahrenheit and Centigrade and the Rockwell hardness of the material after transformation has been completed at a particular temperature is shown on the right. The figure at the bottom of the hardness scale is in every case that obtained by quenching a small specimen from the hardening temperature into brine and represents approximately the greatest hardness of which the particular steel is capable.

The time is shown on a logarithmic scale of which the basis is seconds and this device is employed to keep the graph compact in view of the very short and very long times involved in some of the changes.

The curves themselves show the time required for the austenite to begin transforming, to go halfway, and to finish at any temperature

lower than the temperature at which the austenite is stable. We may therefore use them to visualise how the steel will respond to any mode of cooling from the austenitic state.

The topmost curve which at its upper end approaches asymptotically the equilibrium temperature above which the austenite is completely stable ($Ae_3$ line), represents the beginning of the separation of ferrite in steels containing less than 0·89 per cent. carbon and the separation of surplus carbide in the cases of steels of higher carbon content. It is not necessary for us to consider the higher carbon steels however in this paper.

The second uppermost curve represents the beginning of the breakdown of that portion of the austenite which is still untransformed. This further breakdown produces the iron carbide mixture in which we are most interested.

At the "knee" of the curve (see Fig. 5) these two lines merge and below the knee only a single line is needed to show the beginning of the transformation. The bottom right-hand curve indicates the time necessary for the completion of the transformation at each temperature level.

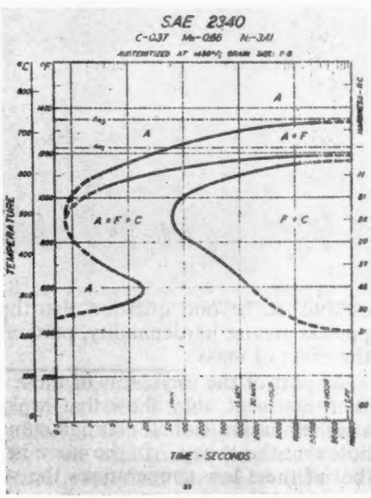


Fig. 5

Austenite alone exists in the area labelled "A." Austenite and ferrite in the area "A" + "F"; austenite and ferrite and carbide in the area "A" + "F" + "C" and in the field to the right labelled "F" + "C" only ferrite and carbide are present because in that area all the austenite has been transformed.

The thin dotted line in the "A" + "F" + "C" area indicates the time for transformation of half the austenite.

The portion of the diagram below 400 degrees F. has been left incomplete as there is still some uncertainty as to what happens in this temperature range.

A few points are worth noting now about these S-curves.

The lower the temperature at which the transformation takes place,

the finer is the structure of the carbide and the greater is the hardness of the material.

An increase in alloy content always retards transformation, particularly above the knee of the curve—compare Figs. 4, 5 and 6—thereby explaining in graphic form the development of oil or air hardening steels by the use of alloying elements.

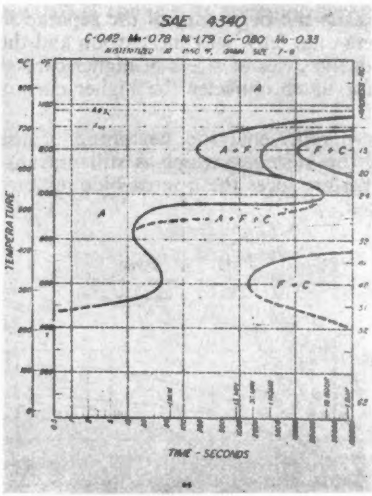

Fig. 6

Increase of grain size shows in lesser degree the same tendency. I cannot devote much time to the subject of grain size—it will therefore have to suffice that every steel has an inherent grain size dependent on the conditions of steel making. Fig. 7 gives some idea of the variations in grain size in specimens of different steels in precisely the same condition of heat-treatment. Appropriate S-curves show that the coarser grain steels have greater hardenability, because the curves have been displaced to the right. Practical experience has established beyond question that the coarser grain steels do in fact possess greater hardenability, particularly in respect of resistance to the effect of mass.

As part of the usefulness of these curves to those concerned with heat-treatment, they show that rapid cooling to a point below the knee retains austenite for straightening while the part is still ductile—note that the " bay " in the curve below the knee in Fig. 5 indicates that at these low temperatures the steel can remain austenitic for a considerable period without in any way affecting its capacity to harden completely on subsequent cooling to room-temperature.

This peculiarity shown by the curves is the basis of the so-called Martempering processes involving a delayed quench by plunging the steel from the hardening temperature into a salt bath held at, say, 400°F., the temperature chosen being that at which martensite forms. The cooling to this temperature must be as rapid as possible to avoid any decomposition of the austenite at higher temperatures. Now in the formation of martensite a small increase of volume takes place and we have in that unfortunate fact the explanation of much of the

distortion trouble which engineers associate with heat-treatment processes. If the surface or near-surface of a part in ordinary quenching is converted to the martensitic condition and the transformation of the core material inevitably takes place later, we have tremendous bursting stresses set up with serious danger of cracking or at least distortion. The steels with greater hardenability show

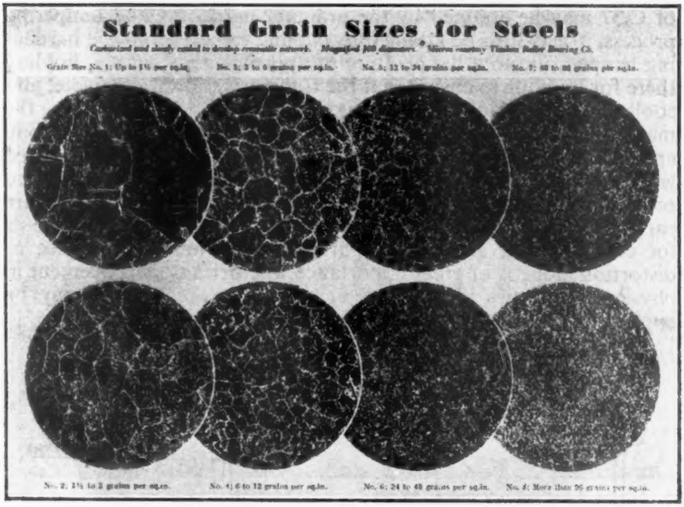


Fig. 7

the greater tendency to crack or distort for the same quenching conditions and the tendencies are aggravated further by any lack of symmetry or by marked changes of section in the parts involved. If, however, we quench in a salt bath held at the temperature of martensite formation and give adequate time for equalisation of temperature throughout the mass of the part, the martensite is formed through the section at a fairly uniform rate with the minimum temperature differential and high hardness can be obtained with the minimum distortion by final cooling in still air.

Too little work on this type of treatment has so far been carried out in this country, but the results obtained in America, particularly with parts in gun mechanism, suggest that with increased use of larger salt bath equipment here, much can profitably be done.

Its application to the heat-treatment of high-speed steel is already well-known here.

Austempering is another process covered by American patents which uses the delayed quench. In this case the idea is to attain the hardness required by a single heating and cooling cycle, instead of by fully hardening and then tempering. The S-curves show the temperature and time required to produce the appropriate hardness without ever producing a fully martensitic structure at all. For example, reference to Fig. 5 will show that while a Rockwell hardness of C.37 may be attained by the ordinary hardening and tempering process, it may also be attained by cooling rapidly from the hardening temperature to a temperature of approximately 375°C., holding there for an hour to ensure that the transformation is complete, and cooling in air. In addition to reduction of distortion by avoiding the maximum volume changes it has been established that plain carbon and low alloy steels have greater ductility and toughness compared with material hardened and tempered in the normal fashion to precisely the same hardness. The effects are most notable with plain carbon steels in light sections as in small springs and delicate tools for clock making and other light industries, but if avoidance of distortion alone is of great importance whether any improvement in physical properties is obtained or not, then the process may be applied with profit to the alloy steels.

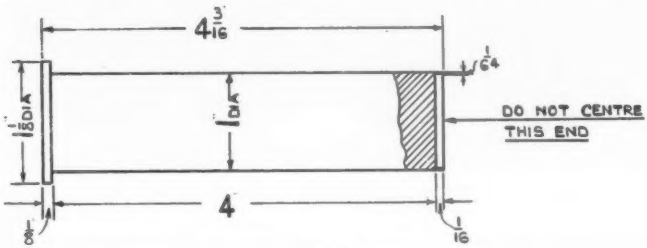


Fig. 8

Automobile axle shafts in 100-ton oil hardening Nickel-Chromium steel to Specification V.13 given in Fig. 2 have shown distortion of the order of $\frac{5}{32}$ in. after hardening at 820°C. in the ordinary way and tempering at 200°C. The Austempering process for these consists of transferring the shafts from the hardening furnace at 820°C.to another furnace at 400°C. holding for an hour and subsequently air cooling. This reduces the distortion to $\frac{1}{16}$ in.

I shall give one other illustration of the value of the S-curves. In annealing operations involving slow cooling in the furnace the question is often asked—" Will it be necessary to cool right down to atmospheric temperature in the furnace ? " The answer may be obtained from the S-curve if it is available for the particular steel to

which the query applies. The curve shows quite clearly the temperature below which it is not necessary to continue the slow cooling, because all the austenite has already been transformed by the time that temperature is reached. This information may save much valuable furnace time.

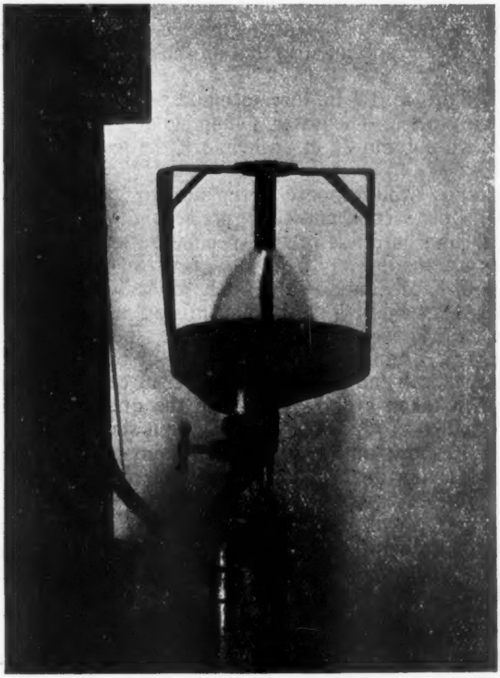

Fig. 9

The S-curves are, of course, laborious to prepare and some time must yet elapse before we have enough of them available to cover most variations in composition. Meantime, particularly while the shortage of alloying elements persists, information of the kind described is frequently and sometimes rather urgently required—most often perhaps with reference to "hardenability" both in respect of actual hardness obtainable and in respect of ability to harden in fairly heavy sections. Many tests have been suggested

with this end in view, but the test method evolved by Walter E. Jominy in the U.S.A. is probably the best and is, I think, the one which is finding most acceptance in this country.

To carry out this test a 1 in. diameter specimen is machined from the sample of steel available with at one end a collar and the other end recessed, as shown in Fig. 8. (The recess is not standard practice.) This specimen is heated to the hardening temperature and quenched in a special rig (see Fig. 9), which applies a rapid water spray to the recessed end of the specimen so that all the cooling takes place from that end.

The water orifice is ½ in. diameter and is ½ in. below the bottom end of the test piece. The water is supplied at a pressure such that it would make a column 2½ in. in height if the test piece were not in position.

The test shows the response of the steel to cooling rates between about 900°F. per second and 40°F. per second.

Obviously the hardness of the specimen after it is cold will fall off as tests are made away from the quenched end face. When the steel has poor hardening qualities the hardness will fall away quickly but the hardness will be high for a surprising distance from this end in a steel with good hardenability. The specimen is therefore examined very carefully after heat-treatment by grinding two flats on it 15 thous. deep and diametrically opposite each other. Hardness tests are then taken every $\frac{1}{16}$ in. from the quenched end and the results plotted to produce the type of graph shown in Fig. 10.

This Fig. 10 shows on one graph the Jominy curves for two different steels, the one having poor hardening quality and the other fairly good in this respect.

These curves can be satisfactorily interpreted only with the aid of the Tables shown in Fig. 11. The cooling rates in these Tables have been established by extensive laboratory experiments and are copied in this instance from the booklet entitled "National Emergency Steels," published by Joseph T. Ryerson & Son, Inc., of the U.S.A.

If we wish to know the hardness which would be obtained from a particular steel in bar form 3 in. diameter water quenched, we note from Table II that a 3 in. dia. bar water quenched cools at the rate of 400°F. per second on the surface and 15°F. per second in the centre. Reference to Table I then shows that the Jominy test piece cools at 15°F. per second, approximately ⅞ in. from the quenched end and therefore the hardness shown on the Jominy curve at this point will be for all practical purposes the same as the hardness of a 3 in. dia. bar at the centre, the cooling rate being almost identical. The surface hardness of the 3 in. round bar can be reckoned in the same way and so can the results of oil quenching this or other sizes of bar covered by Table II.

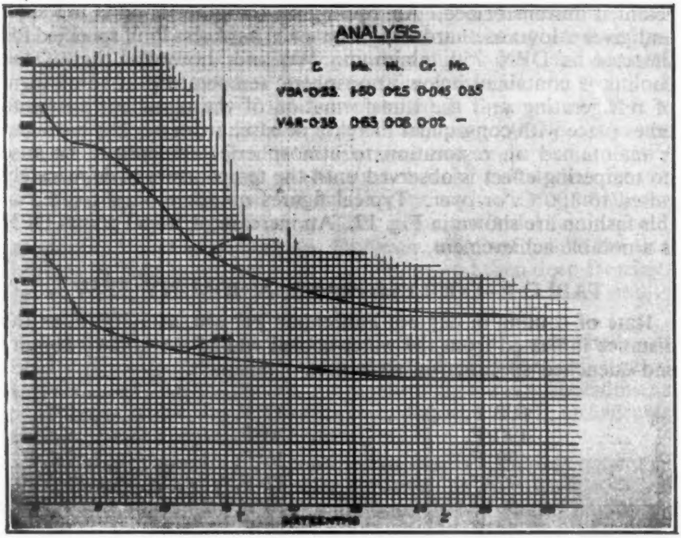


Fig. 10

Knowing the hardness figures at the surface and at the centre to be expected from various diameters of bar in a particular steel, the tensile strength and other properties are also known with reasonable accuracy. The system has been extended to squares and flats and by tempering the Jominy test piece after hardening, still more information can be obtained on the same lines. Enough has, I think, been said, however, for my purpose and anyone whose interest has been stimulated can obtain all the details he requires from existing literature on a most interesting branch of the subject. The articles published in the "Iron Age" in the last two years are particularly helpful.

I should like to revert now to the transformation of austenite and an interesting point on special cooling methods to ensure that in highly alloyed steels the transformation is complete.

We shall consider first, casehardened steel to Specification S.82. This steel has the composition and core physical properties in the fully heat-treated condition given in Fig. 12.

The case contains, of course, carbon of the order of 1 per cent. and in the final hardening heat the oil quench gives rather too rapid cooling to permit complete hardening as some of the austenite is

retained untransformed. Air cooling on the other hand is too slow and gives a low case hardness. The usual hardness limit specified for the case is DPN 750 minimum. We find, however, that if the cooling is contained below atmospheric temperature in some form of refrigerating unit the transformation of the remanent austenite takes place with consequent increase of casehardness. The hardness is maintained on restoration to atmospheric temperature because no tempering effect is observed until the temperature is deliberately raised to 100°C. or over. Typical figures on some parts treated in this fashion are shown in Fig. 12. An increase of 50–60 points DPN is a notable achievement.

## TABLE I—COOLING RATE IN JOMINY TEST

Rate of cooling in degrees Fahrenheit per sec. at 1,300°F. at the distance indicated from the water-cooled end of a standard Jominy end-quenched specimen in sixteenths of an inch.

| | | | | | |
|---|---|---|---|---|---|
| $\frac{1}{16}$ | 600°F. | $\frac{7}{16}$ | 37°F. | 1 | 10°F. |
| $\frac{1}{8}$ | 190°F. | $\frac{1}{2}$ | 30°F. | $1\frac{1}{8}$ | 8·5°F. |
| $\frac{3}{16}$ | 99°F. | $\frac{9}{16}$ | 26°F. | $1\frac{1}{4}$ | 7·2°F. |
| $\frac{1}{4}$ | 72°F. | $\frac{5}{8}$ | 22°F. | $1\frac{1}{2}$ | 5·5°F. |
| $\frac{5}{16}$ | 56°F. | $\frac{3}{4}$ | 18°F. | 2 | 4·3°F. |
| $\frac{3}{8}$ | 44°F. | $\frac{7}{8}$ | 14°F. | | |

Fig. 11 (a)

The refrigeration or deep-freezing of the S.82 parts can be carried out as a separate operation after the normal heat-treatment has been completed and even a few days' delay is not important. A freezing bath containing trichlorethylene to which solid carbon dioxide has been added is quite suitable for the purpose and will cool the parts to −93°F.

Any steel in which austenite is retained in this fashion will respond to deep-freezing treatment and an important application is in the freezing of high-speed steel tools High-speed steel as normally treated contains the retained austenite and even the repeated secondary hardening treatment at 580–600°C. is not completely successful in breaking it down. My own experiments in the application of the freezing process to tools have not been completed in time for quotation here, but Messrs. A. P. Newall & Co. of Possilpark have very kindly given me permission to use results which they have obtained.

## EXPERIMENT ON "DEEPFREEZING."

| | Before freezing. | After freezing. |
|---|---|---|
| Case hardness (DPN) ... ... ... | 783–806 | 840–850 |

In the deep-freezing of high-speed steel lower temperatures still are required and suitable refrigerating units are being produced in the U.S.A. A few are now in operation in this country and Messrs. Newall have added to their reputation for enterprise and technical progress by having one of the first installed in their works. It is a two-stage refrigerator and is capable of extracting 1,000 B.T.Us. per hour at temperatures down to the operating temperature of $-120°F$.

Tools may be hardened in the normal fashion and then frozen for a period of 4 to 6 hours, the usual secondary hardening treatment or treatments being given later. That is the method I favour until experience teaches me otherwise. However, excellent results are also obtained by hardening, secondary hardening and then deep-freezing. Messrs. Newall use the latter sequence and some of the service results they have obtained are shown in Fig. 13.

I have not quoted hardness figures. In general terms these are about 150 points DPN higher for frozen tools than for tools treated in the normal fashion, but an improvement in service life from the frozen tools is frequently noted, even when the actual measurable hardness is not appreciably above normal.

The freezing process has been used to obtain an improvement in service life from tools improperly hardened or from tools softened in grinding, but I hardly need emphasise that it should not be regarded as a cure for faulty workmanship in the earlier processes. In particular it should be noted that it will not harden tools soft on the surface as a result of decarburisation.

The carburising process which is part of any casehardening treatment is quite familiar to us. Steel absorbs carbon at high temperatures if it is surrounded by carbon monoxide from carbonaceous materials heated to the same temperature and the carbon gradually diffuses inwards. In the absence of the carbonaceous materials, however, the reverse process takes place. Carbon is oxidised out of the surface of the steel and to maintain equilibrium diffusion of the carbon outwards proceeds so that the carbon content may be reduced subsequently to a considerable depth. This may happen in the early stages of steel manufacture, in rolling and forging and so on, and to ensure satisfactory hardening of important surfaces the decarburised skin should be removed by machining before heat-treatment. Unfortunately, decarburisation may proceed during the heat-treatment processes themselves and in spite of attention to furnace atmosphere it is as well that final grinding operations are mostly adequate to take away soft skin. Grinding may not be successful, however, when the grinding allowance is small and the decarburisation is deep and for important work it is essential to devote considerable attention to the furnace atmosphere, bearing in mind that when a neutral atmosphere is difficult of attainment a slightly oxidising one producing a light protective scale is to be preferred to a reducing

one which may produce a cleaner looking job. It is specially important to note that moisture can give very serious trouble indeed with decarburisation and must be avoided. However, by the production of synthetic furnace atmospheres in charcoal gas producers, by the use of scrubbed products of the combustion of town's gas, or by the decomposition of ammonia, a variety of atmospheres are available and reputable furnace makers give reliable advice. For the odd occasion in ordinary muffle furnaces good use can be made of a box of fresh charcoal in each corner.

## TABLE II—COOLING RATES OF ROUND BARS

Rate of cooling in degress Fahrenheit at 1,300°F. at surface, half-radius and centre of different sized rounds—quenched in water and oil.

| Diameter "D." | Surface. | Half-Radius. | Centre. |
|---|---|---|---|
| 1-in. Round | | | |
| Water quenched ... | 850°F. | 135°F. | 100°F. |
| Oil quenched ... | 120°F. | 53°F. | 45°F. |
| 2-in Round | | | |
| Water quenched ... | 550°F. | 46°F. | 32°F. |
| Oil quenched ... | 58°F. | 24°F. | 18°F. |
| 3-in. Round | | | |
| Water quenched ... | 400°F. | 27°F. | 15°F. |
| Oil quenched ... | 30°F. | 12°F. | 9°F. |
| 4-in. Round | | | |
| Water quenched ... | 100°F. | 14°F. | 8°F. |
| Oil quenched ... | 15°F. | 6½°F. | 5½°F. |

Fig. 11 (b)

The question of decarburisation should not be dismissed without consideration being given to salt bath treatments. It would seem that the salt bath method of heating provides the complete answer to decarburisation troubles, but this is far from being the case. The difficulty is this. Salts which will carburise are well known and readily available. Salts which will decarburise with incredible rapidity are equally readily purchased. Salts which are neutral and will do neither in the normal hardening temperature range 760–900°C. apparently don't exist, although so-called neutral salts are sold unblushingly every day. This does not create a serious situation when we can simply avoid decarburisation by ensuring slight carburisation using 5–10 per cent. sodium cyanide in the bath. Unfortunately, there are other occasions when neither carburisation nor decarburisation can be tolerated, *e.g.*, (*a*) when reheating carburised parts which have been turned on certain areas after carburising to keep

these areas soft or (*b*) when hardening and tempering small parts to fine limits of surface hardness. In category (*a*) a carburising salt will harden the areas which must be kept soft and the use of a decarburising one will entail loss of hardness on the areas which must be hard. Typical parts in category (*b*) are common in the manufacture of small arms. In an example very familiar to me the actual size of the part is only ½ in. long, the material 0·8–0·9 per cent. carbon steel. The hardness figures specified are for service reasons very important viz. DP650–700. The surfaces must be kept free from scale. The obvious treatment is hardening and tempering in salt baths. If, however, the hardening bath is slightly carburising, false hardness figures will be obtained by the production of a hard skin and the lower the load used in Diamond Pyramid Hardness testing, the greater the error will be. When I was involved, so-called neutral salts were tried, but they stayed neutral for a few minutes only and then began to decarburise, false readings then being obtained as a result of the production of a soft skin. All sorts of salts were tried without success and finally a compromise treatment was evolved. The parts were hardened only twelve at a time in a tiny basket immersed in the salt and the time of immersion kept down to the minimum required to attain the hardening temperature in each of the twelve parts. When this minimum time had been established as 45 seconds the operater adhered to it with the aid of a stop-watch. Some decarburisation still took place, but the time of immersion was so short that the depth of decarburisation was negligible and did not affect the hardness readings. If larger quantities were immersed at one time they naturally took longer to attain the hardening temperature throughout the bulk and the parts at the outside were decarburised sufficiently to scrap them.

In the course of dealing with these and similar problems it was observed that the rapidity of decarburisation not unnaturally depended on the carbon content of the steel being treated and that a salt containing less than 8 per cent. sodium cyanide would decarburise 0·8–0·9 per cent. carbon steel while 16 per cent. cyanide was the absolute minimum necessary to avoid the decarburisation of parts in steel having a carbon content over 1 per cent.

Discussion of carburisation and decarburisation lead us naturally to the subject of nitriding. It has been dealt with most adequately in the Proceedings of the Institution already and I propose to deal with two aspects of it only.

The first aspect need not detain us long. As is well known, the nitriding of a steel surface causes that surface to grow, the growth being of the order of 0·001 in. per inch. This puts the surface layers under stress in compression which is valuable in developing resistance to fatigue. To initiate fatigue failure we must apply in sufficient magnitude fluctuations of stress in tension or alternations of stress

between tension and compression as in reversed bending. If the magnitude of these stresses is such that failure will ultimately take place by fatigue, it has been found that the production of initial internal compression stresses in the surface of the material will increase the endurance substantially and may avoid failure entirely. The reason is simple. When a tension stress is applied to a surface already stressed in compression, the final tension stress is reduced directly by the amount of the initial stress in compression.

## NICKEL-CHROMIUM CASE-HARDENING STEEL—B.S. SPECIFICATION S.82

| | | |
|---|---|---|
| Carbon ... ... ... | Not more than | 0·18 per cent. |
| Manganese ... ... ... | ,, ,, ,, | 0·50 per cent. |
| Nickel ... ... ... | Between | 4·0 and 4·5 per cent. |
| Chromium ... ... ... | ,, | 1·0 and 1·6 per cent. |
| Molybdenum ... ... | Not more than | 0·50 per cent. |

Carburise at a temperature between 850 and 900°C.
Refine by heating at 830°C. and cooling in air or oil.
Harden by heating to 760°C. and quenching in oil.

| | |
|---|---|
| Ultimate stress ... ... ... | Not less than 85 tons per sq. in. |
| Elongation ... ... ... | Not less than 12 per cent. |
| Izod value ... ... ... | Not less than 25 ft. lbs. |

These mechanical test values are to be obtained from $1\frac{1}{8}$ in. diameter samples.

Fig. 12

The initial compression stress may be produced by peening or shot-blasting and there has been much work done in this fashion in the last few years, particularly in increasing the life of all sorts of springs.

The purpose of these remarks is to emphasise that the pre-compression can be produced by a nitriding operation which can, therefore, be of considerable value in certain circumstances where the high surface hardness produced at the same time is not necessarily important or even required.

The other aspect of the nitriding process with which I wish to deal brings me back once again to high-speed steel tools and salt baths.

Sodium cyanide baths produce in ordinary casehardening operations a very hard wear resisting skin which owes some of its properties to the fact that both nitrides and carbides are produced at the steel surfaces and we have a combination of the nitriding and cementing processes. This effect is produced at the normal cyanide hardening temperatures between 800 and 950°C. If, however, the temperature of the cyanide bath is reduced to 570°C. the carburising effect is eliminated and a nitriding action alone takes place.

Now high-speed steel has a composition rendering it suitable for nitriding, and a good deal of work has been done which demonstrates clearly that considerably increased life in service can be obtained from a variety of tools given the nitriding treatment as a last operation, *i.e.*, after hardening and final grinding. The nitriding imparts to the tools increased resistance to abrasion which when allied to the hot-hardness of the basic material increases the cutting efficiency by resisting chip wear.

One British firm whose annual expenditure on cutting tools was approximately £9,000 in 1939 and earlier years has reduced the figure to approximately £5,000 as a direct result of the introduction of the nitriding process.

The most spectacular result in my own experience was obtained from D-bit drills used in the manufacture of barrels for small-arms. Nitriding increased the life of these by 5 to 10 times and a serious bottle-neck in tool production was eliminated.

Turning tools, milling cutters, screwing tools, slotting tools, hobs, ordinary drills, have all been found to respond in most cases to the treatment, the general expectation of increased life now being established at about 100 per cent. as a minimum. In my experience, however, there may be no obvious improvement at all where heavy cuts are being taken.

It should be noted that some hobs and milling cutters show the increased efficiency only until the tools are reground and after grinding they fall back to normal, but many tools maintain their improvement after a large number of regrinds without any repetition of the nitriding treatment.

One other proviso should be made. Delicate tools which give little support to the cutting edge may show signs of brittleness and chip at the edge after nitriding. In such cases the length of immersion in the nitriding bath may be cut down to as little as five minutes so as to produce just the merest skin of extra hardness ; or a diffusion process after nitriding may be carried out to reduce the concentration of nitrides on the cutting edge. In any event, the proposal to nitride a particular tool should not be abandoned until it has been established that no modification of the process will meet the requirements.

The nitriding operation should be carried out in a liquid salt bath composed of 60 per cent. sodium cyanide and 40 per cent. potassium cyanide.

The evolution of nitrogen from a new bath is not satisfactory and it must therefore be aged at 570°C. for 15 hours before being put into use, but this requires to be done only when starting up a new bath.

Topping-up additions to the bath should be made with a mixture of 70 per cent. sodium cyanide and 30 per cent. potassium cyanide.

The potassium cyanide content is necessary to keep the melting point of the mixture reasonably below the operating temperature.

Please note that the pot must be a plain mild steel pot and the thermocouple must have a mild steel sheath because the salt absorbs nickel from any alloy steel in contact with it and this nickel interferes with the nitriding process by plating out on the parts being treated. The bath must, therefore, be kept nickel free.

With the continued heating the carbonate content of the bath becomes quite substantial with constant increase of sluggishness and melting point. If the temperature of the bath is lowered it will be found that the carbonate begins to fall to the bottom at about 500°C. and on further cooling may be removed from the bottom with a perforated ladle when the bath is between 470 and 480°C. After the ageing process the melting point of the nitriding salt mixture is approximately 430°C.

## THE "DEEPFREEZING" OF HIGH-SPEED STEEL TOOLS

Service results obtained by Messrs. A. P. Newall & Company, Ltd.

| Type of Tool. | Type of High-speed Steel. | Number of Parts Normally Produced. | Number of Parts Produced After Deepfreezing. |
|---|---|---|---|
| $\frac{3}{16}$ in. hex. trimming die ... | 18/4/1 | 100,000 | 568,000 |
| $\frac{43}{64}$ in. dia. drills ... ... | 16% Tungsten | 100* | 300–500* |
| B. & S. forming tool ... | 18% Tungsten | 210* | 600* |
| Milling cutter, $\frac{9}{64}$ in. ... | 18% Tungsten | 6,000* | 13,000* |
| $\frac{3}{4}$ in. S.A.E. tap ... ... | 18% Tungsten | 4,900* | 10,000* |
| Parting tool ... ... | 18% Tungsten | 800 | 1,900 |
| Heavy turning tool ... | 18% Tungsten | 50* | 100* |
| $\frac{1}{4}$ in. dia. pointing tool ... | 18% Tungsten | 10,000* | 30,000* |

* Per grind.

Fig. 13

### Operation.

The tools should be pre-heated but the temperature is not important as long as they are warm when immersed in the nitriding bath.

The tools should be immersed in the nitriding salts for 1 hour at 570°C., although this period may be reduced for delicate tools.

When the tools are withdrawn from the nitriding salts they should be drained, cooled in still air and washed free from salt in hot water. Where in the light of experience it is decided to carry out a diffusion process on delicate tools this should be done in a neutral salt at 570°C. for 1 hour.

**Inspection.**

The surface hardness of the tools after nitriding should be DPN. 1,000–1,100, using a 5 kg. load on the diamond. It is appreciated that hardness testing using this light load requires great care, but it should be necessary to do only 2 or 3 tools out of a quantity nitrided together.

The case depth after 1 hour in the nitriding salts should be 0·0015 in. and the case is shown up quite clearly on a cross section etched with 3 per cent. nital.

The appearance of the surface of the tools after nitriding and washing is a good guide to the accuracy of the process, as they should have a metallic lustre as distinct from the dull grey appearance which arises from an unsatisfactory bath mixture. Tools for treatment should be in the finally ground condition, clean and dry.

The process will not compensate for the faulty treatment of tools in the normal hardening and secondary hardening operations and the decarburised surfaces of the original high-speed steel bars must be removed, as decarburised areas become extremely brittle as the result of nitriding operation.

The ageing of the nitriding bath oxidises some of the cyanide to cyanate. The commercial cyanides have an original cyanate content of the order of 1·25 per cent. This is increased to over 5 per cent. by the ageing process and the bath in this condition will give satisfactory work. The nascent nitrogen absorbed by the steel is derived from the cyanate and a new bath has not the necessary nitriding capacity.

Ordinary ammonia gas nitriding is not a suitable substitute for the process I have described, as there appears to be an excessive build up of nitrides causing severe brittleness. When the cyanate in the salt bath decomposes it provides finely divided carbon as well as nitrogen. This fine carbon deposited on the tool surfaces appears to inhibit the absorption by the tool of excess nitrogen.

I mentioned earlier that alloy pots and thermocouple sheaths should be avoided, because nickel plates out on the tools being treated and gives a soft skin. Actually the molten cyanides form a very definite electrolyte and advantage is to be obtained by insulating the tools from the pot containing the salts and from the furnace generally. Maximum hardness will be produced in the shortest time with avoidance of the microscopic surface pitting which is sometimes associated with the process. Suspension of the tools from a glass rod across the top of the pot will meet the insulation requirement very satisfactorily.

Another modern heat-treatment process produces hard wear-resisting surfaces; I am referring now to the induction hardening treatment which came to us from the U.S.A.

We have been familiar for many years with heating processes dependent on high-frequency electric induction—particularly in the

melting of steel. The application of related heating methods to the surface hardening of steel has made tremendous strides, especially in mass production plants.

Fig. 14 shows how the work is handled when all is going well. The bulk of the substantial electric equipment is not shown, but the business end of it is, viz., the heating coil. The current supplied to this coil may have a frequency of about 10,000 cycles per second, or 100,000, or 1,000,000 depending on the type of machine which again depends on the type of work to be treated.

Fig. 14

Cylindrical parts requiring surface hardening are ideal for treatment by this process and where depths of hardening over 30 thous. are permissible the motor-generator type of machine giving frequencies up to 12,000 cycles/sec. is the one chosen on the score of cost. It is available in 3 or 4 sizes of 50,100, 125 and 150 kilowatt

capacity—10 kilowatts being regarded as the basic requirement per sq. in. of surface to be heated.

As the parts are progressed through the induction coil the high-frequency current raises the surface temperature rapidly and as the parts emerge from the other end of the coil they are quenched in a cone of water, which is produced by jets incorporated in the induction coil itself.

Obviously, there is an optimum rate for passage through the coil. If the rate is too fast the hardening temperature will not be attained and if it is too slow, over-heating will take place. The proper rate is therefore established experimentally for each part and the equipment controlled accordingly.

The capacity of these machines is enormous and parts like automobile gudgeon pins can be case-hardened on one machine of this type at the rate of 1,000 an hour.

The method of heating is very efficient from the point of view of conservation of energy. About 80 per cent. of the energy in the induction coil goes to the heating of the part inside it. In addition, only a small volume of metal is heated in relation to the total volume of the part. These two things combined represent a huge saving in energy by comparison, for example, with the ordinary case-hardening process entailing the heating throughout of the parts and the compound and the boxes and the reheating of the parts afterwards.

As only the surface of the part is heated in the induction process the distortion is small or non-existent.

As the time of heating is a matter of seconds only the amount of scale produced is negligible and grinding allowances can be very small or grinding dispensed with entirely.

One operator only is required for the machine and in spite of its huge capacity its many advantages suggest that it might be installed with profit even if it stands idle half the week.

A chrome-molybdenum steel containing 1 per cent. chromium and 0·40 per cent. carbon treated in a 10,000 cycle/sec. machine will give a surface hardness of DPN 750 min. with a case depth of 35 thous.

A 0·55 per cent. carbon steel will give DPN figures of 800 minimum with the same case depth.

In fact, the surface will show the highest hardness of which the steel is capable in commercial treatment.

The core is unaffected by the process and a steel with high tensile strength and good ductility will still have these properties in the core after treatment.

A sample of a nickel chromium steel hardened in this fashion is available for examination.

Where thinner cases than 30 thous. are essential the higher frequencies must be employed, because they produce a more rapid

increase of surface temperature with consequently less penetration. A spark-gap oscillator for generating the current will produce frequencies between 50,000 and 200,000 cycles per second and a valve oscillator similar in principle to a radio transmitting unit will produce current between 100,000 and 100 million cycles per second. With such equipment the thinnest cases can be produced.

The high frequency machines can also be used for the surface hardening of parts such as gear wheels, where a thin case is required over the tooth profiles. With the low frequency machines the tooth is heated throughout its thickness before the surface at the root has attained the hardening temperature.

Induction heating is not, of course, confined to surface hardening processes, but can be applied to brazing, billet heating and innumerable other purposes. Those interested may obtain all the information they require from the electric furnace companies who are supplying the equipment in this country.

Great progress has been made in other heat-treatment fields concerned, for example, with non-ferrous metals and cast iron, but these metals are worthy of a paper devoted to them alone. My present purpose will be served if I have stimulated interest in some aspects of steel treatment which are worthy of exploitation.

I could not have prepared the paper and slides without the assistance of members of my staff at Albion Motors, Ltd., to whom I am indebted. I am indebted also to the Albion Company for permission to publish the paper.

*The discussion on this paper will be published in the next issue of the Journal*

# INSTITUTION NOTES

## *January, 1946*

**January Meetings.**

5th North-Eastern Graduate Section. Social Evening to be held at the Newcastle and Gateshead Gas Co's. Demonstration Theatre, St. John St., Newcastle-on-Tyne, at 6-30 p.m.

7th Coventry Graduate Section. A lecture will be given by R. R. Brittain, Grad. I.P.E., on "Designing for Efficient Production," at the Technical College, Coventry, Room A5, at 6-45 p.m.

7th Yorkshire Section. A lecture will be given by E. W. Forster, B.Sc., on "Electronics in Production Engineering," at the Hotel Metropole, Leeds, at 7-00 p.m.

8th Luton and District Section. Film Show on Grinding—Universal Grinding Wheel Co.—at the Small Assembly Room, Town Hall, Luton, at 7-00 p.m.

8th Birmingham Graduate Section. A Discussion Meeting will be held at the James Watt Memorial Hall, Great Charles Street, Birmingham, at 7-15 p.m.

8th North-Eastern Graduate Section. A lecture will be given on "Production Planning and Control" by G. W. M. Blewitt, Esq., at the Newcastle and Gateshead Gas Co's. Demonstration Theatre, St. John Street, Newcastle-on-Tyne, at 6.30 p.m.

9th Manchester Graduate Section. A lecture will be given by J. W. Gardom, Esq., on "Modern Foundry Practice," at the College of Technology, Manchester, at 7-15 p.m.

11th Leicester and District Section. Joint Meeting with the Institute of Economic Engineers when a lecture will be given by W. T. Laxton-Roberts, M.I.Ec.E., A.M.I.P.E., on "Time Study," at the Leicester College of Technology, Leicester, at 7-00 p.m. This lecture will be illustrated by lantern slides.

12th Yorkshire Graduate Section. "Short Papers" by Graduates and Students at the Great Northern Hotel, Leeds, at 2-30 p.m. "The Manufacture of Gauges" by N. Herbert, Grad. I.P.E., Stud. R.Ae.S.; "Material Supply and Stores Control" by A. D. G. Fitzjohn, Stud. I.P.E., Stud. I.Mech.E.; "The Use of Charts and Graphs for Production Control" by N. Sykes, Grad. I.P.E., Grad. I.Mech.E., Grad. I.E.E. (Section President).

**January Meetings**—*cont.*

15th Wolverhampton Graduate Section. The lecture to be given by D. W. Goodreid, Esq., on "Application of Hydraulic Power to Machine Tools," has been postponed.

15th Wolverhampton Section Lecture on "The Layout of Factory Buildings and Plant for Efficient Production" by S. Gilbert, Esq., at the Dudley and Staffordshire Technical College, Dudley, at 6-30 p.m.

16th Sheffield Section. A lecture will be given by C. J. Dadswell, Ph.D., M.I.M.E., on "Mechanical Production in a Modern Steel Foundry," at The Royal Victoria Station Hotel, Sheffield, at 6-30 p.m.

16th Preston Section. A lecture will be given by T.P.N. Burness, M.I.P.E., on "Modern Methods of Production of Machine Tools," at the Canteen of British Northrop Loom Co. Ltd., Daisyfield, Blackburn, at 7-15 p.m.

16th Birmingham Section. Lecture on "Electro-Plating as a Protection and a Decoration" by Ernest Dobbs, Esq., at the James Watt Memorial Institute, at 7-00 p.m. This lecture will be illustrated by films.

17th South Wales and Monmouthshire Section. A lecture will be given by Prof. H. W. Swift, M.A., B.Sc., of Sheffield University, on "Deep Drawing of Metals," at the South Wales Institute of Engineers, Park Place, Cardiff, at 6-30 p.m.

17th London Section. A lecture will be given by Dr. J. D. Jevons on "Deep Drawing and Pressing," at the Institution of Mechanical Engineers, Lecture Hall, Storey's Gate, St. James's Park, London, S.W.1, at 6-30 p.m.

17th Glasgow Section. A lecture will be given by F. W. Hopkinson, A.M.I.Ae.E., on "The Maintenance of Aircraft," at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, at 7-15 p.m.

17th Manchester Section. A lecture will be given by K. G. Fenelon, M.A., Ph.D., on "The Foreman—his Training and Function in Industry," at the College of Technology, Manchester, at 7-15 p.m.

18th Coventry Section. A lecture will be given by Dr. C. M. Blow on "A Review of the Development of Rubber-to-Metal Bonding," at Coventry Technical College, Room A5, at 6-45 p.m.

18th Eastern Counties Section. Discussion on "Unification of Screw Threads." Details to follow.

**January Meetings**—*cont.*

18th Western Section. A lecture will be given by L. E. Broome, A.M.I.P.E., on "Personnel Management," at The Grand Hotel, Broad Street, Bristol 1, at 6-45 p.m.

18th Manchester Section. A lecture will be given by K. G. Fenelon, M.A., Ph.D., on "The Foreman—his Training and Function in Industry," at the Mechanics Institute, Crewe, at 7-15 p.m.

19th Manchester Section. A lecture will be given by K. G. Fenelon, M.A., Ph.D., on "The Foreman—his Training and Function in Industry," at Liverpool University, Brownlow Hill, at 2-30 p.m.

19th Nottingham Section. A lecture will be given by E. G. West, Ph.D., B.Sc., on "The Effects of Development in Light Alloys on Future Design," at the Technical College, Shakespeare Street, Nottingham, at 2-30 p.m.

21st Derby Sub-Section. A lecture will be given by S. C. Roberts, F.C.W.A., M.I.I.A., on "Costing as Applied to Production," at the School of Art, Green Lane, Derby, at 6-30 p.m.

21st Halifax Section. A lecture will be given at the Technical College, Huddersfield, on "Automatic Electrical Control Gear," arranged by Igranic Electric Co., Ltd., at 7-00 p.m.

24th North-Eastern Section. To be arranged.

25th Lincoln Sub-Section. A lecture will be given by H. H. Harley, C.B.E., M.I.P.E., on "Broaching," at the Lincoln Technical College, at 6-30 p.m.

26th Yorkshire Graduate Section. Visit to Courtaulds, Ltd., Bradford, Textile Manufacturers, at 2-30 p.m.

**February Meetings.**

4th Yorkshire Section. A lecture will be given by A. F. Brockington, Esq., on "Surface Treatment by Electrolysis and Anti-Corrosion Finishes," at the Hotel Metropole, Leeds, at 7-00 p.m.

4th Coventry Graduate Section. A lecture will be given by T. C. Parker, Esq., on "Cold Up-Setting and Thread Rolling," at the Technical College, Coventry, Room A5, at 6-45 p.m.

7th Leicester Section. A lecture will be given by T. C. Parker, Esq., on "Developments of Cold Heading and Thread Rolling," at the Leicester College of Technology, at 7-00 p.m. This lecture will be illustrated by lantern slides.

**February Meetings**—*cont.*

9th Birmingham Section. An informal dance will be held in the Grosvenor Room, Grand Hotel, on Saturday, February 9th, 7-00 p.m. to 11-45 p.m.

9th Manchester Graduate Section. Works visit to Ferguson Pailin, Ltd., Higher Openshaw, Manchester.

12th Luton and District Section. A lecture will be given by Dr. Heywood on " Modern Scientific Heat Treatment of Steel," at The Small Assembly Room, Town Hall Luton, at 7-00 p.m.

13th Preston Section. A lecture will be given by A. R. Palmer, Esq., on " Gravity Diecasting of Aluminium Alloys," at the Harris Institute, Corporation Street, Preston, at 7-15 p.m.

14th South Wales and Monmouthshire Section. A lecture will be given by F. Baker, M.I.P.E., on " Principles of Interchangeable Manufacture," at the South Wales Institute of Engineers, Park Place, Cardiff, at 6-30 p.m.

14th London Section. A lecture will be given by R. H. Streete, Esq., on " High Frequency Heating," in the Lecture Hall, Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, at 6-30 p.m.

14th Wolverhampton Graduate Section. Visit to Messrs. F. H. Lloyd & Co., Ltd., James Bridge Steel Works, nr. Wednesbury, at 2-00 p.m.

15th Western Section. A lecture will be given by W. Whitworth Taylor, Esq., on " Milling," at the Grand Hotel, Broad Street, Bristol, 1, at 6-45 p.m.

15th Coventry Section. A lecture will be given by E. Ingham, B.Sc., on " Modern Mining Machinery," at the Coventry Technical College, Room A5, at 6-45 p.m.

18th North-Eastern Graduate Section. A lecture will be given by A.C. Foskew, Int. A.M.I.P.E., on " Inspection Methods and Their Applications," at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m.

18th Halifax Section. A lecture will be given by H. C. Town, M.I.P.E., on " Hydraulics as Applied to Machine Tools," at the Technical College, Halifax, at 7-00 p.m.

18th Derby Sub-Section. A lecture will be given by I. S. Morton, Esq., on " Drilling Research," at the School of Art, Green Lane, Derby, at 6-30 p.m.

20th Sheffield Section. A lecture will be given by A. H. Jay, Ph.D., M.Sc., on "Application of X-Ray to Industrial Problems," at the Royal Victoria Station Hotel, Sheffield, at 6-30 p.m.

**February Meetings**—*cont.*

20th Manchester Section. A lecture will be given by K. J. Hume, B.Sc., A.M.I.P.E., on "Precision Measurements by Optical Methods," at The College of Technology, Manchester, at 7-15 p.m.

20th Birmingham Section. Lecture on "Single Spindle Automatic Screw Machines" by W. Ogilvie, Esq., and S. Ackrill, Esq., at the James Watt Memorial Institute, at 7-00 p.m.

21st Wolverhampton Section. A lecture will be given by H. Fairbairn, A.M.I.P.E., on "Latest Developments in Die Castings," at the County Technical College, Wednesbury, at 6.30 p.m.

21st North-Eastern Section. To be arranged.

21st Glasgow Section. A lecture will be given by R. J. Hird, B.Sc., on "The Production of Coal Cutting and Handling Machinery," at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, at 7-15 p.m.

22nd Lincoln Sub-Section. A lecture will be given by A. P. Young, Esq., O.B.E., on "Managerial Problems during the Transition Period," at the Lincoln Technical College, at 6-30 p.m.

23rd Yorkshire Graduate Section. A lecture will be given by J. E. Hill, M.I.P.E., A.M.I.Mech.E., on "The Production of Fine Finishes," at the Great Northern Hotel, Bradford, at 2.30 p.m.

— Wolverhampton Graduate Section. A lecture will be given by J. Styles, Esq., on "Design and Manufacture of Special Cutting Tools," illustrated with drawings and specimens, at the Dudley and Staffordshire Technical College, Dudley. Date to be arranged.

**January Committee Meetings.**

8th The Education Committee, at 10-30 a.m., at the Imperial Hotel, Birmingham.

8th The Membership Committee, at 12-30 p.m., at the Imperial Hotel, Birmingham.

18th The Finance and General Purposes Committee, at 2-30 p.m., at Institution Headquarters.

21st The Research Committee at Loughborough College, Loughborough, Leics.

The Technical and Publications Committee meet every Wednesday at 5-30 p.m. in the TEMPORARY Committee Room at 36, Portman Square, London, W.1.

SOUTHERN SECTION.—There was a most interesting Educational Visit to the Pirelli-General Cable Works, Ltd., Eastleigh, on Wednesday, 28th November.

The tour started with a visit to the plant and maintenance department, covering the boiler house, gas mixing plant, rotary converter and transformer rooms supplying the various services to the factory. The foundry, fitting and machine shops, where new machines and repairs to existing plant are carried out, were also visited.

The power and telephone cable-making factories, covering a wide range of operations, such as stranding, paper-lapping, drying and impregnating, and lead sheathing and armouring, were next visited, and details of these operations were explained to the members. Particular interest was shown in the Pirelli Lead Extruding Machine, which was designed and manufactured in these works. Being a continuous operation, it is quite a new departure in this field when compared with the hydraulic type of press.

From here, the members were taken to the rolling mill and wire-drawing department. These operations are the first in cable-making, when the copper ingots are rolled at a high temperature to approximately a $\frac{5}{16}$ in. diameter rod, and then cold-drawn to wire of the diameter required, which is in some cases as small as ·001 in. diameter. The tinning of copper wire was also inspected in an adjoining building.

The high tension Test Bay and Chemical Laboratory were next visited. Here the members saw a 66,000-volt cable sealing end or terminal flashed over at 240,000 volts.

In the Chemical Laboratory, spectographic analysis and various other methods, which are normally employed in the testing of cable-making materials, were demonstrated.

Unfortunately, insufficient time had been allowed for a complete inspection of the works, and it was decided to adjourn to the Works' Canteen for tea at this point. After tea, Mr. Butler, deputising for Mr. Allen, the Section President, proposed a vote of thanks to the management of the Company for the facilities afforded, enabling members to visit their works.

Several members having to leave at this stage in order to catch trains, etc., only a limited number were able to visit the remainder of the works, consisting of plastic extrusion and moulding, and the manufacture of cable accessories, such as joint boxes, sealing ends, automatic switches, current transformers and the patented oil-filled cable apparatus.

At the conclusion of the visit, Mr. Butler proposed a particular vote of thanks to Mr. Cottell and Mr. Tobia for providing such an instructive and interesting afternoon.

SHREWSBURY SUB-SECTION. At the November lecture meeting of this Sub-Section, held on November 24th, 1945, Mr. E. W. Hancock, M.B.E., presented a paper entitled "Jig and Fixture Design." This was the first lecture-meeting to be held at Oakengates, all previous lectures having been held at the Technical College, Shrewsbury.

The lecture, which was enjoyed by members and visitors present, was followed by a short discussion.

Letters of thanks have been sent to Mr. Hancock and to Mr. R. F. Beaton, Principal of the Walker Technical College, Oakengates.

**Personal.**

L. Bunn, Esq., A.M.I.P.E., has been invited to sit on the Technical and Publications Committee. Mr. Bunn has accepted the invitation.

A. T. Davey, Esq., M.I.P.E., the General Manager of Charlesworth Bodies (1931) Ltd., of Coventry and Gloucester and a Director of Manufacturing Services, Ltd., has been elected an Alderman of the City of Gloucester. Mr. Davey was a Founder Member of the Institution, and the first Honorary Secretary.

J. Napier, Esq., Int. A.M.I.P.E., has been appointed Chief Planning Engineer to Messrs. Courtaulds, Accrington. His business address remains the same, as Messrs. Courtaulds are taking over the Bristol Aeroplane Company's factory.

Capt. K. F. Dormer, R.E., Stud.I.P.E., has recently returned home after nearly four years' service in India and Burma, with a Mention in Despatches for engineering services rendered while with the mechanical equipment unit on the Imphal-Kohima-Burma Front last year.

**Books Received.**

*Quasi-Arc Welding Manual.* Published by the Quasi-Arc Co., Ltd., Bilston, Staffs. Price, 3/6 net.

*The Manufacture and Production of Aluminium Alloy Forgings and Stampings.* Issued by the Technical Committee of the Wrought Light Alloys Development Association.

*Drawing Boards and Tee Squares.* Published by the British Standards Institution, London. Price 2/- net, post free.

*Cast Iron in Building*, by R. Sheppard, F.R.I.B.A. Published by George Allen & Unwin, Ltd., London. Price 7/6d. net.

*Adhesives for Metals*, by N. A. de Bruyne, M.A., Ph.D. Issued by Aero Research, Ltd., Cambridge.

*Calling All Arms*, by Earnest Fairfax. Published by Messrs. Hutchinson & Co., Ltd., London. Price 7/6d. net.

**Issue of Journal to New Members.**

Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

**Important.**

In order that the Journal can be despatched on time, copy must reach the Head Office of the Institution by not later than 40 days prior to the date of issue, which will be the first of each month.

## SOME ACTIVITIES OF THE RESEARCH DEPARTMENT

**Turning Tests.**

The first series of severe duty tests on various cemented carbide tools has been completed and fine finish turning tests on non-ferrous alloys have been resumed. A short series of fine finish turning tests on magnesium alloys with and without coolant is now almost complete.

EFFECT OF POINT GRINDING ON ACCURACY OF DRILLED HOLES.

Drills ... ... ... 5/8 in. dia. standard.
Material drilled ... 35-T steel.
Cutting conditions ... 326 r.p.m. 0·014 in. feed/rev. No coolant.

| Drill | Drill Condition | Drill Dia. | Relative lip height (inches) | | | Hole No. | Hole Accuracy | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1/8 in. Depth | | 3/8 in Depth | | 5/8 in. Depth | |
| | | Inches | 3/32 in. rad. | 3/16 in. rad. | 9/32 in. rad. | | Hole dia. Ins. | Amt. over nom. dia. Ins. | Hole dia. Ins. | Amt. over nom. dia. Ins. | Hole dia. Ins. | Amt. over nom. dia. Ins. |
| A | As supplied | ·6252 | ·007 | ·011 | ·011 | A1 | ·665 | ·040 | ·666 | ·041 | ·658 | ·033 |
| | | | | | | A2 | ·648 | ·023 | ·650 | ·025 | ·630 | ·005 |
| | | | | | | A3 | ·661 | ·036 | ·664 | ·039 | ·658 | ·033 |
| A | Reground by Research Dept. | ·6252 | ·001 | ·002 | ·001 | A4 | ·627 | ·002 | ·627 | ·002 | ·628 | ·003 |
| | | | | | | A5 | ·636 | ·011 | ·631 | ·006 | ·630 | ·005 |
| | | | | | | A6 | ·632 | ·007 | ·632 | ·007 | ·631 | ·006 |
| B | As supplied | ·6250 | ·002 | ·003 | ·0045 | B1 | ·646 | ·021 | ·638 | ·013 | ·634 | ·009 |
| | | | | | | B2 | ·631 | ·006 | ·632 | ·007 | ·632 | ·007 |
| | | | | | | B3 | ·634 | ·009 | ·632 | ·007 | ·631 | ·006 |

Fig. 1.

**Drilling.**

Drilling tests on various steels, cast irons and non-ferrous alloys have been continued. In addition to the usual tests using 5/8 in.

diameter drills, particular attention has been devoted to small drills of approximately $\frac{1}{4}$ in. diameter. A series of tests using 1 in. diameter drills has constituted part of an investigation on machinability.

An investigation of some of the practical effects of inferior drill grinding has now been carried out. Examples of differences in lip height together with the effects on hole diameter at various depths are shown in Fig. 1. The tables indicates results obtained with $\frac{5}{8}$ in. diameter drills as supplied by two makers and also the improvements effected by regrinding the inferior point.

**Field Research.**

Various field researches have been carried out, including a series of tests on drilling machines. Tests on the deflections of machine

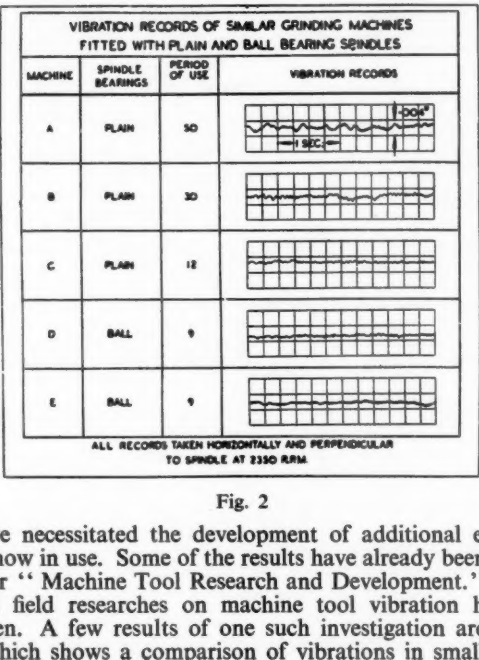


Fig. 2

tools have necessitated the development of additional equipment which is now in use. Some of the results have already been included in a paper " Machine Tool Research and Development."

Several field researches on machine tool vibration have been undertaken. A few results of one such investigation are given in Fig. 2, which shows a comparison of vibrations in small grinding machines fitted with ball and plain bearings. This series of investigations is linked with observations being made in the Research Department on the general performance of ball and roller bearings. A typical result of surface finish observations on different parts of one roller bearing is shown in Fig. 3.

**Milling.**

Investigations on milling are proceeding and recent research includes negative rake tests and tests on finish milling of magnesium alloys under various conditions.

**Grinding.**

A short series of tests on the grinding of cemented carbide tipped tools of different grades, using various special and commercial

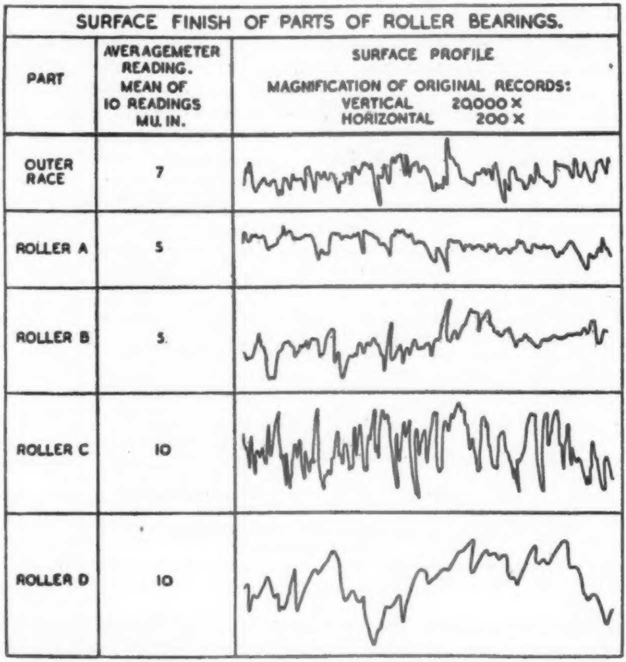


Fig. 3

grinding wheels has been completed. The main criteria in these tests were rate of stock removal and resultant surface finish when grinding under controlled conditions.

D. F. GALLOWAY,
Director of Research.

*December*, 1945.

# Research Department : Production Engineering Abstracts

## (*Prepared by the Research Department.*)

NOTE.—*The Addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough. Readers applying for information regarding any abstract should give full particulars printed at the head of that abstract including the name and date of the periodical.*

### HEAT TREATMENT.

**The Place of Radiant, Dielectric and Eddy-Current Heating in the Process Heating Field,** by L. J. C. Connell, O. W. Humphreys, and J. L. Rycroft. (*The Journal of The Institution of Electrical Engineers, October*, 1945, *Vol.* 92, *Part II*, *No.* 29, *p.* 385, 9 *figs.*)

If the fullest advantage is to be gained from the rapid developments which have taken place in connection with radiant and high-frequency methods of heating, care must be exercised in the selection of the applications for which they are recommended. Although many processes can be carried out more effectively by the new methods, there is still a very real place for contact and convective heating, and the paper facilitates this selection. It reviews the various methods of heating, indicating the physical laws and practical considerations by which they are governed and the rates of heating which may be obtained. An endeavour is then made to classify, in terms of their technical requirements, the types of application for which each process is best suited, and the results are summarised in two very useful tables, which show respectively the characteristics of the various heating methods, and a classification of heating processes and methods of heating. Finally, several specific applications are considered in some detail, and it is shown that processes having a superficial similarity may nevertheless possess features which are of sufficient importance to warrant the use of different methods of heating.

**Electrode Salt Baths.** (*Machine Shop Magazine*, *October*, 1945, *Vol.* 6, *No.* 10, *p.* 88, 1 *fig.*)

The article describes a small furnace unit which is suitable for the medium-size works, where its cost has previously delayed its use.

**Production Cold Treatment,** by A. J. T. Eyles. (*Mechanical World*, *November* 16*th*, 1945, *Vol.* 118, *No.* 3072, *p.* 543, 1 *fig.*)

Its use for shrinking, testing, hardening, stabilising metals and increasing tool life is described, and details of sub-zero chilling machines are given. Cold treating procedures commonly used are given for high-speed tool steel with particular reference to drills, taps, broaches, milling cutters, saws and form tools.

### COOLANT, LUBRICANT.

**Lubricants for Press Work,** by J. S. Murphy. (*Machine Shop Magazine*, *October*, 1945, *Vol.* 6, *No.* 10, *p.* 82.)

In press work extreme pressures occur, and compounds such as the fatty acids, fats and oils of the animal and vegetable group, which are readily adsorbed, are necessary. Other characteristics required are :—good body, no harmful effect

on work or dies, ease of degreasing, and antiseptic properties making them harmless to operators. Materials which have been popular are discussed and their limitations pointed out. Of new compounds the most versatile are the water-soluble soda-base greases. Neutralising eliminates staining effects and the lubricants are stable at high temperatures with a high load-carrying capacity. For dilution, water is preferable for dissipation of heat and easy removal after use. For running-in new dies, the addition of sulphur is an advantage. In blanking there is a definite increase in tool life from the use of a lubricant with heavy work. Lubricants for drawing steel, brass, aluminium, and magnesium are suggested.

**Cutting Oils for Machining Metals,** by E. L. Cady. (*Metals and Alloys, August,* 1945, *Vol.* 22, *No.* 2, *p.* 431.)

General, covering both non-ferrous and ferrous materials. Types and characteristics of cutting oils ; handling and treating oils ; oils for specific operations ; oils in relation to cutting materials.

(*Communicated by The British Non-Ferrous Metals Research Association.*)

## EMPLOYEES, APPRENTICES.

**The Boy and His Job : An Industrial Effort,** by Frank Holliday. (*The Engineer, 19th and 26th October,* 1945, *Vol. CLXXX, Nos.* 4684 *and* 4685, *pp.* 298 *and* 318.)

The re-organisation of the apprenticeship scheme at an aircraft works is described. All boys are interviewed carefully before commencing work, and opinions on them are supplemented later by mechanical aptitude and intelligence tests. The boys are then graded in four categories. Details of the procedure and some of the results obtained are discussed in detail, with reference to actual cases.

## FOUNDRY, CASTING.

**Cast VS. Forged Steels,** by C. E. Sims. (*Foundry, May,* 1945. *Abstract from Metals and Alloys, August,* 1945.)

Fatigue and tensile tests were made on forged and centrifugally cast aircraft engine cylinder barrels made of chrome-molybdenum steel. The results of the tensile tests showed that the forgings had somewhat better longitudinal properties, but inferior transverse properties. The average of both directions for the forging was the same as for the casting. The main difference between the two products was that the casting had uniform properties in both directions, while the forging had definite directional properties. The results of the fatigue tests of these two products were so closely similar that, so far as these tests are concerned, no superiority can be shown for either the forged or the cast steel. One method proposed for relieving a forging bottleneck, therefore, is to cast forge blanks that will approximate closely the size and shape of the forge blank before it enters the final die. Two advantages would be gained by this procedure, namely, smaller die blocks with fewer impressions would be needed, and the final cast-forging would have properties similar to a forging. A series of cast blanks was made of a chrome-moly steel, the size and shape of a commercial wrought blank. The cast blanks were risered so that some of the casting would be sound and others unsound. The castings were forged, quenched and tempered to 331 to 341 Brinell. Tensile and impact data from these castings indicate a small general improvement in the mechanical properties as a result of forging, with marked improvement in soundness. This improvement could not be relied upon to eliminate defects in unsound casting. Starting with cast blanks, a forging could be made at the rate of 450 per hour by one man and one hammer. Forgings from rolled stock could be made at the rate of 131 per hour. This comparison does not take into account the cost or time involved in making the rolled stock

or cast blank. A study was made of seamless tubing made from centrifugal casting in comparison with tubing from pierced billets. Examination of S.A.E. 4130 tubing made by these processes indicate that, so far as the outside surfaces are concerned, there is very little difference, but that the inside surface is better on the specimens from pierced billets. In both tensile and flattening tests, the tubes showed about equal properties.

(*Communicated by the U.S. Office of War Information, London.*)

**Centrifugally Cast Aircraft Parts,** by J. F. B. Jackson. (*Aircraft Production, November,* 1945, *Vol. VII, No.* 85, *p.* 511, 8 *figs.*)

The extensive use of centrifugally cast aircraft-engine cylinder sleeves is well known. It is also possible to produce components of irregular and asymmetrical contour in high-tensile alloy steels. Examples are shown, and the control of manufacture and properties attainable are described.

## GEARING.

**The Effect of Chemical Surface Treatment on the Scuffing of Gears,** by H. D. Mansion. (*Power Transmission,* 15*th October,* 1945, *Vol.* 14, *No.* 165, *p.* 880, 2 *figs.*)

Part II. From the preliminary tests the phosphate treatments appeared to be the most effective. Direct scuffing tests were made on gears treated by each phosphate process, and running-in tests were made on all except one. The results of the tests are given in detail with comments.

**Notes on Gear Steels,** by L. Sanderson. (*Machinery Lloyd,* 10*th November,* 1945, *Vol. XVII, No.* 23, *p.* 79.)

The selection of gear steels must consider both service and manufacturing methods, *e.g.*, ease of machining, warping during hardening, and the practicability of grinding. Research into the causes of wear is by no means complete, and it can only be said that certain specific conditions produce rapid wear, but the steel must also be ductile, capable of withstanding shock, noiseless and strong ; hence high quality gears are being made from alloy case-carburising steels. Close control of heat-treatment is essential. Air- and oil-hardening nickel chromium molybdenum steels can also be used for certain cases where carburising is not feasible. Designers of gears should allow for later heat-treatment. The methods of heat-treatment for each type and for the associated H.S.S. hobs and cutters, are given.

## HEATING, VENTILATION

**Ventilation for the Factory.** (*Production and Engineering Bulletin, August,* 1945, *Vol.* 4, *No.* 32, *p.* 289, 6 *figs.*)

Notes are given on the application of recognised first principles for the promotion of health and efficiency.

## MACHINE ELEMENTS.

**High-precision Running Centres for Accurate Work,** by F. M. Birch and J. Lunzer. (*Machinery,* 25*th October,* 1945, *Vol.* 67, *No.* 1724, *p.* 459, 4 *figs.*)

Accurate and heavy turning, with limits of 0·0002-inch on size and ovality, and grinding operations tolerating a run-out of 0·0002-inch, can be handled consistently and continuously with a type of high-precision running centre recently introduced. The centres are intended for : light work at high speeds, and precision finishing operations, including diamond turning, and grinding

work ; high-production work and heavy work to fine limits, including interrupted cuts, using tipped tools ; capstan work, including heavy form-tool cuts ; and capstan and form-tool work to fine limits. Four series have been specifically designed to suit each class of work. The bearings and other features of the designs are discussed and compared with other types.

## MACHINING, MACHINE TOOLS.

**British Machine Tool Industry Reports on Its Future.** (*The Machinist, 17th November*, 1945, *Vol.* 89, *No.* 32, *p.* 1103.)

The Machine Tool Trades Association has recently issued a report on its future prospects and policy. The Association seeks the setting up of a single Government Authority specifically charged with keeping continuously in touch with the industry, co-ordinating the views of various Government departments when it is necessary to present them to the trade, and serving also as the means for presentation of the co-ordinated views of the trade. It is further recommended that active co-operation between the Government and the trade should be achieved by a Machine Tool Advisory Council comprising equal representation of Government and the trade. During the war, the compilation of the vital statistics of the trade has proved valuable, and this should continue. This country went to war with both its industrial and Government factories equipped with machine tools of an average age of well over twenty years. It was very difficult to expand to meet the immediate pre-war and war-time demands, though this was finally achieved. It is suggested that the turnover of the industry should be increased by the faster replacement of existing machine tools, and the Inland Revenue should examine the possibility of stimulating the demand for new machine tools by means of taxation legislation. The importance of keeping the machine tool output of the country up to a certain minimum level emphasizes the absolute necessity of keeping its labour force as intact and permanent as possible. It is dangerous in normal times to carry the dilution of skilled labour in the machine tool industry too far. Approximately one-third of British production was exported before the war, and there is no reason why we should not become such a competitor again. Combined market research is not suitable for application to the sale of machine tools, and more individual methods are desirable. It is the intention of the M.T.T.A. to make London the recognized centre for international machine tool exhibitions. Subject to certain important safeguards, freedom to import machine tools into this country should be restored as soon as possible. The manufacturing industry of this country will receive stimulation from overseas competition. The M.T.T.A. is collaborating in establishing a new and separate Research Association built on the foundation of what has already been done by the Institution of Production Engineers. Development, as distinct from research, can best take place within individual organizations. The industry will undoubtedly retain those aspects of war-time rationalization which have permanent value. There has been some misinformed talk about "Gap" machines, *i.e.*, machines that could only have been produced in this country at a financial loss. A list of such machines is given and the report recommends official encouragement of their production. When very large surpluses come up for disposal the continuation of the interim Government scheme might severely handicap the sale of new machine tools, and the rate of disposal of any particular type of Government surplus is jeopardizing the sale of similar new tools, and should be subjected to regulation.

**Negative Rake Machining,** by B. G. York. (*Machine Shop Magazine, October,* 1945, *Vol.* 6, *No.* 10, *p.* 46, 3 *figs.*)

The principles of negative rake cutting are indicated. Requirements for successful operation are high speeds and feeds, robust fixtures, and machines

in good condition. When milling, climb milling is to be preferred. The best angles for the setting of the cutter blades for steel are 8 to 10 deg. radial and 5 to 10 deg. axial. Cutting speeds and rate of metal removal for various grades of steel are given, and a typical example of cutter design is worked out in full. The use of fly-wheels is only advantageous when they are accurately balanced. Relationships between cutting speed and power needed for turning, and a typical calculation, are also given.

**Cutting with Carbides—Milling.** (*Machine-Tool Review, Sept.–Oct.*, 1945, *Vol.* 33, *No.* 199, *p.* 95, 11 *figs.*)

Large tips and complicated cutter profiles should be avoided. A radius or chamfer should always be used at corners. The rake angles of cutters are, for practical purposes, subject to the same design considerations as those for turning tools. Flywheels are almost a necessity as a means of avoiding violent torsional oscillations of the machine spindle due to the rapid feeding of cutters having relatively few teeth. Cutting speeds, as for turning, can be used, but it is usually better to reduce by 10 per cent. Facing cutters should be wider than the job ; the ideal at which to aim is shown. In order to determine the cutter loading the chip thicknesses should be determined and tables give the machine feeds to be used to obtain the correct minimum and maximum chip thicknesses. Negative rake milling is closely allied to climb cutting in view of the importance of maintaining chip thickness with a slotting cutter. The chip, being thick, tends to prolong cutter life and obviates the initial rub at the start of the cut of each tooth which occurs when milling in the conventional manner. As with facing cutters, the chip thickness must be calculated not in the direction of feed, but radial to the cutter axis. An expression for determining chip thickness and machine feed per tooth is given and an example is worked out.

**Diamond Charged Mandrels for Small Hole Grinding,** by F. C. Victory. (*Industrial Diamond Review, November*, 1945, *Vol.* 5, *No.* 60, *p.* 268, 1 *fig.*)

Diamond-charged grinding wheels increase the efficiency of stock removal in holes below $\frac{1}{4}$ in. diameter, and holes as small as 0·030 in. can be ground. Diamond-grinding differs from lapping, since grinding permits the correction of hole location, increases the hole size, feed, and the surface speed is several times that of lapping. The speed required is the limiting factor for hole size. The mandrel should be of dead soft cold-rolled steel, and suitable dimensions are given. The correct size of grit is indicated, and the general operation technique is described. Advantages claimed for mandrels compared with diamond-impregnated wheels are : easier dressing or truing, improved stiffness, suitability for specific jobs, and lower cost. An editorial comment, with the author's subsequent reply are appended.

**German Special-purpose Horizontal Boring Machines,** by R. H. P. Nott. (*Machinery, 15th November*, 1945, *Vol.* 67, *No.* 1727, *p.* 541, 12 *figs.*)

German machines designed to speed-up production of parts for internal combustion engines, in the manufacture of which the majority of machining problems are related to boring, include : a semi-automatic boring machine for the boring and facing of crankshaft bearing housings ; and machines for finish-boring and turning crankshaft bearings, boring crankshaft-bearing housings, rough and finish-boring automobile gearboxes, boring crankcases, crankshaft bearings, and crankshaft-bearing shells, and precision-boring pump-housings, pistons and bushings.

## MANUFACTURING METHODS.

**Time and Motion Study,** by John W. Hendry. (*The Automobile Engineer, September*, 1945, *Vol. XXXV*, *No.* 466, *p.* 362, 3 *figs.*)

The handling of material averages in the region of 23 per cent. of the labour cost of a product, yet insufficient attention has been paid to reducing it by motion study. Logical steps to be taken are :—substituting " flow line " for batch work, using mechanical aids for movement and loading/unloading and giving close attention to the laws of motion economy. The conclusions are : handling time should be reduced to a minimum ; components should travel direct from operator to operator ; collecting stations should be established to cut down small loads ; gravity should be used where possible ; work should flow towards despatch, and sub-stores should be created near work benches and issues made from main stores in schedules to cut down waiting for materials.

**Continuous Methods in Cast-Steel Bomb Production.** (*Machinery*, 1*st November*, 1945, *Vol.* 67, *No.* 1725, *p.* 477, 10 *figs.*)

Machining practice at a specially-built factory is described. The processes include heat treatment, cleaning, and machining on both special purpose machines and heavy duty autos.

## MATERIALS, MATERIAL TESTING.

**Micro-Mechanical Testing of Metals,** by N. Mironoff. (*Welding*, *September*, 1945, *Vol. XIII*, *No.* 8, *p.* 352, 6 *figs.*)

A new type of apparatus for carrying out alternating bending tests on metals is suitable for testing welds, and results are given of tests conducted on a welded chromium-molybdenum steel specimen. The apparatus is simple and easy to handle. The small test pieces do not require any special preparation, and the tests can be carried out in a few seconds.

## MEASURING METHODS, INSPECTION.

**Checking Pitch Diameters of Precision Screw Threads,** by Prof. Earle Buckingham. (*Machinery*, 8*th November*, 1945, *Vol.* 67, *No.* 1726, *p.* 516, 1 *fig.*)

In checking the pitch diameter of a screw thread by measuring over pins or wires, the measurement is affected not only by the lead angle and thread angle, but also by the profile or cross-sectional shape of the thread. There are three general cases to be considered : (1) Screw helicoid ; (2) Involute helicoid ; and (3) Intermediate profiles. All the equations for calculating the measurement over pins or wires are either approximations or a series of indeterminate equations which must be solved by successive trials. The writer has derived an equation for the position of a wire in the tooth space of an involute helical gear, and he adapts this for screw-thread measurement. An example is worked out.

**Quality Control,** by H. Howell. (*Aircraft Production*, *November*, 1945, *Vol. VII*, *No.* 85, *p.* 539, 5 *figs.*)

A detailed comparison is made of compressed limit gauging methods with measurement check in dimensional quality control practice.

**Dynamic Balancing.** (*The Automobile Engineer*, *September*, 1945, *Vol. XXXV*, *No.* 466, *p.* 365, 2 *figs.*)

Two recently developed Avery machines have been specially designed to facilitate rapid and accurate correction for dynamic balance. Both the magnitude and the angular position of the out-of-balance error are automatically indicated, and because of the cradle principle employed there is no uncompensated residual balancing moment. The procedure is so simple that an unskilled person can operate the machine after brief instruction.

**Gudgeon Pin Fits.** (*The Automobile Engineer, September*, 1945, *Vol. XXXV, No.* 466, *p.* 356, 1 *fig.*)

The safe working of the gudgeon pin in its hole has been attained by ensuring minimum tolerances of the order of 5–7 micro-inches between gudgeon pin and bore. This high accuracy can only be obtained in mass-production by further developing the methods of gauging. Equipment has been developed in the form of instruments with two- and three-point measurement, which are briefly described. The three-point method is preferred because of simplicity of setting the instrument in the bore to be measured.

## PLASTICS, POWDER, METALLURGY.

**Standard Nut-type Inserts for Plastic Mouldings,** by M. Freund. (*Machinery*, 25*th October*, 1945, *Vol.* 67, *No.* 1724, *p.* 455, 7 *figs.*)

The design and purpose of nut-type inserts are discussed and a scheme for standard types submitted.

**Post-war Horizons for Powder Metals,** by P. Schwarzkopf and A. Reis. (*The Machinist*, 10*th November*, 1945, *Vol.* 89, *No.* 31, *p.* 1077, 6 *figs.*)

Part I. Progress has been so rapid that currently the process can compete on a price basis with casting, forging and machining in the manufacture of certain machine parts in ferrous, copper-base and some other alloy materials. Any process is based upon a balanced set of operations : (1) production of the powder ; (2) compacting ; and (3) sintering. The properties of the powders are discussed, including broad characteristics, and suitability for compressing and sintering.

## RESEARCH.

**Investigation on Cutting-Tool Angles,** by M. Littmann and R. Neumann, (*Engineering*, 5*th*, 19*th and* 26*th October*, 1945, *Vol.* 160, *Nos.* 4160, 4162, 4163. *pp.* 261, 304, *and* 321, 20 *figs.*)

The importance of cutting angles is first indicated by reference to the work of various investigators. A nomenclature is suggested, and the inter-relation of the various angles carefully reviewed. The disadvantages of the American definition of top rake are shown, and particular attention is paid to the derivation of the angle between the direction of chip flow and the plane perpendicular to the axis of the workpiece. Side-rake and back-rake together determine the maximum slope of the tool face and the direction of the maximum slope, and these angles can be connected by nomograms. Provided that other conditions remain unchanged, a tool will work more efficiently if its true rake is made equal to the angle of maximum slope and if the direction of maximum slope is the direction of chip flow. If practical research or practice itself have indicated the value of one of the rake angles, the selection of the other tool angles is facilitated by the use of a combined diagram. As in all cases, owing to the influence of the nose and the end-cutting edge, the flow of chip will never be perpendicular to the side-cutting edge, the direction of maximum slope should not be chosen at right angles to the side-cutting edge and therefore the true rake of the ideal tool must be combined from the side-rake and back-rake. From theoretical considerations, the conclusion may be drawn that the back-rake should also be made negative if the side-rake is negative. An increase of the true-rake in the positive direction decreases the strength of the tool. An increase of the true-rake in the negative direction increases its strength. The decreasing and increasing strength is related to the tangent of the decreasing and increasing wedge angle.

## SMALL TOOLS.

**Tooth Design Formulae for Angular Milling Cutters and Taper Reamers,** by L. W. Silk. (*Machinery*, 15*th November*, 1945, *Vol.* 67, *No.* 1727, *p.* 549, 2 *figs.*)

The formulae given enable all the necessary dimensions to be calculated for machining the flutes in angular milling cutters and taper reamers. They provide for the correct dividing-head setting angle and the amount of depth to sink the cutter.

**Bearing Lands and Negative Rakes Prolong Cutting Tool Life,** by Mark W. Purser. (*The Machinist*, 17*th November*, 1945, *Vol.* 89, *No.* 32, *p.* 1116, 7 *figs.*)

Important progress in the solution of wear, chatter, and set-up difficulties with cutting tools is claimed by lapping a slight land just below the cutting edge and by stoning a negative rake around this cutting edge. The land can be lapped quickly and effectively by lapping the tool against the actual workpiece after the tool is rigidly set in working position. Facing or forming tools, drills or milling cutters can be done by similar methods. It is claimed that longer tool life and improved finish are obtained, less control of nominal rake and clearance angles is required, it is easier to hold required dimensions, and set-up is speeded through greater ease of locating tools in machine. A theory to explain these facts is suggested.

**Training Industrial Diamond Polishers.** (*Industrial Diamond Review*, *November*, 1945, *Vol.* 5, *No.* 60, *p.* 253, 10 *figs.*)

The author describes the processes involved in making diamond tools with particular reference to those not found in gem stone practice. They include the selection of natural and cleavage stones, their shaping and polishing, the machine tools used, and the use of diamond powders and lead dops. The requirements for rake and relief are explained, and the necessary protractors and radius gauges described.

## SURFACE, SURFACE TREATMENT.

**Hard Steel Surfaces,** by Donald Taylor. (*Automobile Engineer*, *October*, 1945, *Vol. XXXV*, *No.* 467, p. 401.)

Maximum hardness may entail loss of desirable physical properties such as resistance to shock, and it is customary to employ a hard skin with a tough or fibrous core, obtained by: (1) Effecting a chemical change on the surface; (2) Effecting a physical change; or (3) The addition to the original surface of some hard facing material either electrically or mechanically. Cyaniding has limitations and is not considered a heavy carburiser. Pack and gas carburisation methods are heavy case producers with a time cycle of about 5 hours. The gas method permits of delayed application of the energising agent, and the type and amount of carbon can be controlled. Nitriding is an excellent method for large numbers of small parts. It does not cause distortion and provides a case of exceptional hardness, but it takes about 90 hours to produce a case thickness of 0·030 in. Flame surface hardening has solved many problems and has been proved an economical and easy way of producing a hard surface in a short time. Its use has undoubtedly prolonged the life of large gear wheels which could not have been hardened economically by any other means. The induction process has solved many production difficulties during the war in producing cases up to 0·04 in. in as short a period as five seconds. Hard chrome skins are being increasingly applied to tools, dies, wearing surfaces, etc., and as a means of building up. The case stands up to abrasion, corrosion and erosion. Welded hard faces can be laid on large fixed constructions *in situ*, and effect the quick return to

working conditions of plant which might otherwise be down for days or weeks. Spraying has its own particular sphere, but should be used with discretion, remembering that it is not fixed on the parent metal as are the other hard surfaces.

**Increasing Fatigue Resistance by Shot Peening.** (*Machinery, 25th October,* 1945, *Vol.* 67, *No.* 1724, *p.* 449, 10 *figs.*)

Shot peening is a method of cold-working by subjecting the stressed surface of the parts to a rain of metallic shot thrown at a relatively high velocity, each shot making a small pit in the metal and stretching it radially. There is a plastic flow of the surface fibres throughout a layer from 0·005- to 0·010-inch in depth. In the equilibrium that results, the surface fibres are in residual compression, while the inner fibres are in tension. When working stresses are applied that would ordinarily increase the tension stress on the surface, they are offset by the residual stress in the surface layer. Since fatigue failures generally result from tension stresses and not from compressive stresses, the result is a considerably greater fatigue life. Certain laboratory tests show that shot peening increased the life of hypoid gears by as much as 600 per cent. ; aircraft engine crankshafts, 900 per cent. ; steering knuckles, 475 per cent. ; welded joints, 310 per cent. ; transmission main shafts, 520 per cent. ; and helical springs, 1,370 per cent. Two methods of shot peening have been developed ; in the first, with which this article is mainly concerned, the shot is thrown on the work from a centrifugal wheel that revolves at high speed ; in the second, the shot is directed on the work by compressed air. The control of shot-peening must take into consideration the duration of exposure, the size and hardness of the shot, the velocity, the work coverage and direction of the shot, the rate of shot breakdown and removal, and the hardness and other physical properties of the work. These factors are discussed, and are illustrated by descriptions of machines and treated components. A method developed as the best means of measuring peening intensity is based on the principle that if a thin flat strip of hard steel is shot-peened on one surface only, the stretching of the surface fibres will cause the strip to assume a curved shape. The amount of this curvature is, therefore, a measure of the compressive stress to which the specimen is subjected.

**Electrolytic Methods of Polishing Metals,** by S. Wernick. (*Sheet Metal Industries, November,* 1945, *Vol.* 22, *No.* 223, *p.* 1951, 5 *figs.*)

Part 9. The electrolytic polishing of carbon steels is described. Applications other than complete polishing include : de-burring, machining, increasing adhesion of subsequent deposits, giving improved protection, and polishing of inaccessible areas.

**Modern Installations for Spraying Parts,** by E. J. Cartwright. (*The Machinist,* 10*th November,* 1945, *Vol.* 89, *No.* 31, *p.* 1069, 1 *fig.*)

This article indicates the faults that should be avoided, and details the procedure that should be followed, with reference to a particular spraying unit.

## WELDING.

**Developments and Trends in American Industries.** (*S*-7534, *U.S. Office of War Information.*)

Extracts from various sources give a broad survey of important technological and scientific developments and trends in welding, flame-cutting, soldering, brazing and related techniques in the United States in recent years. They cover the major aspects of this industry and suggest probable post-war developments.

(*Communicated by the U.S. Office of War Information, London.*)

**The Weldability of Steels,** by R. F. Tylecote. (*Engineering Materials, August*, 1945, *Vol. III, No.* 7, *p.* 143, 4 *figs.*)

Weldability is defined as a combined property of base metal and filler metal, the measure of which is the capacity to produce crack-free and mechanically satisfactory joints by as many as possible of the known welding processes. The principal metallurgical property affecting weldability is that of hardness, a function of its composition and its rate of cooling. These with "crackability" are the properties to be determined in the measurement of weldability. The "carbon equivalent" guide to the hardenability of steels of Dearden and O'Neill and the Reeve cracking test are described, and the following resulting conclusions are given. In America the Jominy end-quench test is used in conjunction with a bend test. The idea is that the steel manufacturer carries out both of these tests on each heat of steel, and is therefore in a position to give the required information to his customers, who deduce the welding conditions from curves in their possession. These correspond to their own welding conditions.

**Quick Removal of Broken Studs,** by A. F. Morton and W. F. Kramer. (*Machine Shop Magazine, September*, 1945, *Vol.* 6, *No.* 9, *p.* 62, 1 *fig.*)

With electric arc welding, nuts are welded on studs and they are screwed out. About 20 studs can be removed per 1½ hours, whether hardened or unhardened. The authors claim that cost is about 20 per cent. less than if a machinist does it.

**The Welding of Non-ferrous Metals,** by E. G. West. (*Sheet Metal Industries, September*, 1945, *Vol.* 22, *No.* 221, *p.* 1618, 12 *figs.*)

Part 6. Resistance welding equipment. Principles and control methods.

**Flash Welding,** by I. S. Morton. (*Machinery Lloyd*, 10*th November*, 1945, *Vol. XVII, No.* 23, *p.* 67, 9 *figs.*)

The principles of flash welding are explained, and the requirements for its proper utilisation for a wide range of work are indicated. Examples of the flash welding of sections, pipe work, small tools, airscrew hubs, and anchor cables are given, particular stress being laid on its advantages compared with alternative processes.

**Production of Service Trucks.** (*Welding, November*, 1945, *Vol. XIII, No.* 10, *p.* 441, 13 *figs.*)

The article describes the equipment and procedures of the welding department of Vauxhall Motors, Ltd., for the production of the Bedford truck. The company manufactures a large part of its own welding plant, and the salient features of such plant are reviewed. Spot welding guns form one of the principal items of equipment produced, and details are given. Seam welders up to 200 kVA, fully automatic and pneumatically operated, are also made, and particular attention has been given to the electrodes and mountings. Outstanding developments have been: the materials used in the bearings, spindle and electrode, the electrode trimming device, and the "constancy of the work output" in feet per minute. The spot welders built have a capacity of 50 kVA, are pneumatically operated and water-cooled. The uses of the machines in truck construction are described. Arc welding, flash, and projection welding are also employed on a large scale. For ensuring standard technique throughout the works a comprehensive set of recommendations has been compiled in a "Weld Directory," and samples of the type of information included are quoted.

**A Large Forged Spot-Welding Machine.** (*The Engineer, 5th October*, 1945, *Vol. CLXXX, No.* 4682, *p.* 270, 2 *figs.*)

The machine has been designed for the purpose of joining fairly heavy mild steel plates and sections, such as are used in structural, boiler, and shipbuilding

work. With it, plates are first fused locally between electrodes, and then, whilst the metal is still red hot, the plates are moved along to bring the weld point between two pressure pads capable of applying a load of up to 80 tons to forge the welded area. By using reasonably close weld spacing on the machine, it is possible to produce water-tight joints without the necessity of caulking. Tests have shown that a spot weld had twice the strength of a rivet for shear and shock load resistance.

**Some Electrical Characteristics of Spot Welding Machines,** by C. L. Railton and A. J. Hipperson. (*Sheet Metal Industries, September*, 1945, *Vol.* 22, *No.* 221, *p.* 1609, 10 *figs.*)

The true measure of the welding capacity of a spot-welding machine is the maximum possible secondary current which the machine can deliver at the weld, at the required duty cycle. The effects on secondary current of throat depth, throat opening, and the amount of magnetic material in the throat were studied. It was found that: (1) An increase in welding current of 76 per cent. was obtained by using the machine at its minimum as against the maximum throat. (2) For a given throat, the secondary current was directly proportional to the open circuit secondary voltage, except at very high currents. (3) The calculated current was found to vary from between 8 to 25 per cent. more than the actual measured secondary current. (4) The kVA demand when giving 10,000 amps at the electrodes at the maximum throat area could be more than halved by reducing the throat to the minimum. (5) The drop in secondary current due to magnetic material in the throat of the machine seems to depend more upon the amount of material present than upon its geometry.

**The Power Supply, Installation, and Servicing of Resistance Welding Machines,** by C. A. Burton. (*Sheet Metal Industries, November*, 1945, *Vol.* 22, *No.* 223, *p.* 1979, 14 *figs.*)

The high single-phase kVA demand and poor load factor necessitates the provision of adequate electric power facilities. The heating factor on the supply transformer and transmission cables is usually extremely small, but, to satisfy voltage regulation limitations the supply voltage should not vary more than $\pm$ 5 per cent. for satisfactory operation. The grouping of resistance welding machines across phases should be carried out to permit equal loading per phase, but it is advisable to avoid connecting resistance welding plant to the neutral or earth return because of voltage fluctuation effects on the lighting system. Where lamp flicker is noticeable, any of the following are advocated: (1) Independent circuits for machine load and lighting fed from separate sub-station distribution boards. (2) Reduction of circuit impedance, and (3) current reduction by phase balancers or series capacitors. Alternative transformer circuits are also described. Considerable economy may be effected by keeping the machine throat as small as possible. Important Supply Authority and Home Office regulations must be observed. For cooling water, unless a really efficient circulating system is planned the plant should be connected to town water supply. Compressed air supply may be assisted by auxiliary storage tanks in the machine. Service and maintenance personnel should be carefully chosen. To ensure successful operation, the basic conditions require: (*a*) The application of correct pressure and heat; (*b*) Suitable electrodes; and (*c*) Clean welding points. A weekly maintenance routine is advocated, and procedure is suggested for spot and multiple spot, projection, seam, and butt welders.

**Metal Bonding.** (*The Automobile Engineer, September*, 1945, *Vol. XXXV*, *No.* 466, *p.* 354, 6 *figs.*)

The Redux process originally developed for the aircraft industry has proved that it has applications of considerable interest to industry in general. These include securing the linings to the plates of clutches, bonding two halves of an

aluminium car door, and for bonding impregnated diamond rings to metal discs for parting-off stock. Design strength considerations are discussed in detail. Processing procedure is also described.

## WELFARE, SAFETY.

**Food at the Factory,** by R. Stent. (*Aircraft Production, November*, 1945, *Vol. VII, No.* 85, *p.* 555, 6 *figs.*)

After the last war many canteens were closed down because of lack of enterprise, and reduced wages. This time unless canteen caterers are able to offer meals at reasonable prices and in large variety the works canteen will be again disregarded. Useful ideas may be gained from American practice. Industrial catering is less common in the U.S., but is well organised in many respects. The outside contractor system is favoured. Notable features which might be adopted here are : cafeteria service, staggering meal breaks, suitable decoration of the dining room, and adequate refrigeration.

**Safeguarding Drop Hammers.** (*Production and Engineering Bulletin, November*, 1945, *Vol.* 4, *No.* 34, *p.* 401, 15 *figs.*)

Stops in the form of props or catches should be used to hold drop hammer tups while the operators are changing dies or have their hands in the danger zone. This article outlines various types of stop that have proved to be satisfactory.

**Design of Machine Tools for Safety and Production,** by William Meyer. (*The Machinist*, 20*th*, 27*th October*, 1945, *Vol.* 89, *Nos.* 28, 29, *pp.* 959, 995, 6 *figs.*)

The author discusses the design features of grinding and milling machines that promote safety for operators, prevent overloads caused by improper handling, and ensure uninterrupted production. The elimination of operational hazards, the reduction of operator fatigue, and versatility of controls are factors to be considered. They all play a prominent part in increasing operating efficiency.

## WORKS AND PLANT.

**The Depreciation of Buildings, Plant and Machinery,** by L. Bennett. (*Mechanical World*, 26*th October*, 1945, *Vol.* 118, *No.* 3069, *p.* 455, 3 *figs.*)

A sound system of depreciation for buildings, plant and machinery is very necessary in any progressive business to provide for replacement. The problems occurring when installing such a system are discussed and a method is put forward for obtaining complete information and recording it in a convenient form.

**Maintenance and Repair Costing,** by L. Bennett. (*Mechanical World*, 9*th November*, 1945, *Vol.* 118, *No.* 3071, *p.* 513, 5 *figs.*)

Co-relating cost control of buildings, plant and machinery, with control of engineers' and builders' maintenance and repair costs enables a correct and balanced view to be taken of all additions, modifications or deletions to plant. An efficient maintenance costing system which will reduce expenditure and at the same time give a full and comprehensive record of where and on what charges are incurred is always possible.

# INDEX TO ADVERTISEMENTS

*As a war-time measure the advertisement section of this Journal is now published in two editions, A and B. Advertisers' announcements only appear in one edition each month, advertisements in edition A alternating with those in edition B the following month. This Index gives the page number and edition in which the advertisements appear for the current month.*



***The fact that goods made of raw materials in short supply owing to war conditions are advertised in " The Journal " should not be taken as an indication that they are necessarily available for export.***


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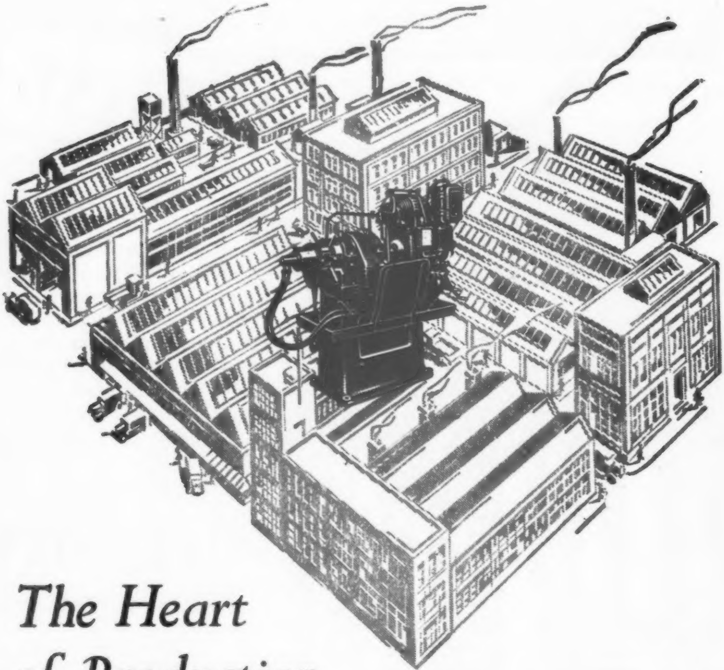
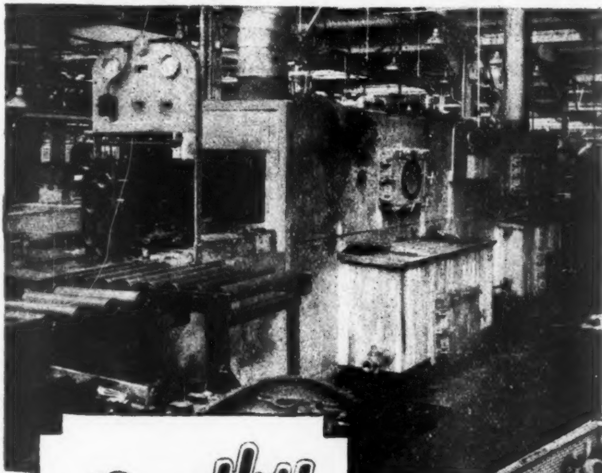


# *Each cleaning problem studied individually*

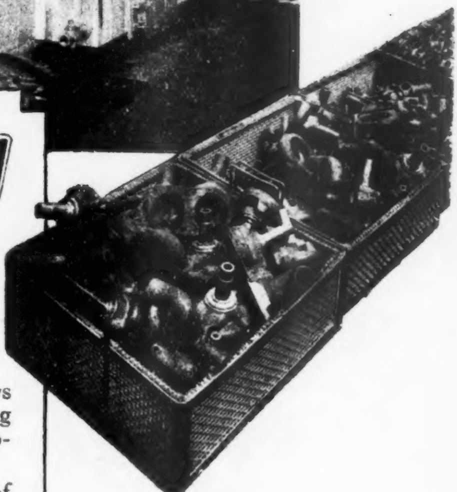


**Bratby**

## INDUSTRIAL CLEANING MACHINES

This illustration shows a machine cleaning crank cases in the production line.

It is equally capable of cleaning small parts in baskets.



*Photographs by courtesy of "Machinery."*

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